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ABSTRACT

This publication contains studies which focus on students' science concepts and the alternative frameworks they use to interpret natural phenomena. Among the specific areas investigated are: conceptions held by Year 11 chemistry students about stoichiometry; how some 9-year-old students interpret the word "solid" to mean hard, unbreakable, inflexible, and not-hollow; children's ideas about floating (noting that many believe the top of an iceberg is the only part floating and if it were cut off, the bottom would sink); pre-instructional alternative frameworks that Year 10 students possess in the area of mechanics; post-instructional frameworks of Year 12 physics students following instruction on circular motion; and chemists' concepts of acids and bases (suggesting that students' difficulties in this area may be more usefully perceived in terms of confusion about the models used in teaching the concepts rather than as a conflict between preconceptions and the scientific view). Other studies involve such areas as curriculum development in science by master's and doctoral students, an examination of authors' claims in prefaces to science textbooks, effects of an activity-based curriculum on student outcomes in chemistry in Thailand, and attitude toward health and knowledge of health issues in nurses, high school students, and primary school students. (JN)

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RESEARCH
IN
SCIENCE EDUCATION

Volume 14

Selections of papers from the Fifteenth Annual Conference of the Australian Science Education Research Association, Monash University, Victoria.

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PREFACE

Fourteen years ago a number of science educators met at Monash University for a two-day conference to discuss their current research interests, research priorities, and the establishment of an Australian research association. A report was published by Colin Power in The Australian Science Teachers Journal (Vol. 16, No.2, 1970, pp. 51-5), and he noted that the participants were involved with the I.E.A. Science Project, the evaluation of new science curricula, Piagetian stages, classroom interaction, teacher preparation, non-technical terms in science teaching, standardised tests, and measures of achievement, laboratory skills, and readability. One of the priorities for future research was more 'precise information about the readiness and difficulties' of pupils. Now, almost one and a half decades later this publication contains a number of reports on pupils' science concepts and the alternative frameworks they use to interpret natural phenomena. Mitchell and Gunstone, for example, describe conceptions held by Year 11 chemistry students in the general field of stoichiometry. Jones demonstrates how some 9-year-olds interpret 'solid' to mean hard, unbreakable, inflexible, not-hollow and Biddulph and Osborne, in their report of children's ideas about floating, note that many believe the top of an iceberg is the only part floating and if it were cut off, the bottom part would sink! Gunstone describes some pre-instructional alternative frameworks that Year 10 girls possess in the area of mechanics while Gardner probes the post-instructional frameworks of Year 12 physics students following instruction on circular motion. Carr examines the chemist's concepts of acids and bases and suggests that students' difficulties in this area may be more usefully perceived in terms of confusion about the models used in teaching the concepts rather than as a conflict between pre-conceptions and the scientific view. West and Pines also caution us. They argue that the research on students' misconceptions and alternative frameworks can lead to narrow perspectives about students' efforts to learn. They present a 'sources-of-knowledge' view of science learning which they believe has important implications for an alternative conception of science education.

This year, in contrast to 14 years ago, there are no reports of Piagetian studies. Dawson and Rowell, however, draw upon Piagetian ideas and recent work on alternative frameworks to explore, empirically, students' conceptual changes in dealing with the displacement of water by solid objects. Curriculum issues still concern science educators today but they differ from those addressed in 1970. Walsh et al. describe attempts to develop a substantial science course for intending primary teachers, Appleton et al. evaluate teachers' guides for the Learning in Science Project (Primary) in New Zealand, Klainin reports on the effects on Thai students of an activity based chemistry curriculum and Atkin, in a report from the workface, tells how teachers in a school successfully developed curriculum units to meet the needs of their pupils.

Issues about teacher education are addressed by Appleton, Happs, and Fawns and several papers report on students' perceptions of health (Garrard & Brumby; Maddock, et al.) and of their learning environments (Tisher). A few papers explore a new theme on pupils' learning strategies. As has been noted already West and Pines present their 'sources of knowledge' view of science learning but, in addition, Hayes and Symington examine children's drawing strategies and Dall'Alba and Northfield report on pupils' cognitive learning strategies. They present a learning strategy profile for a student on four learning tasks.

The preceding paragraphs do not refer to all of the matters that were discussed in the sessions of the fifteenth annual conference of the Australian Science Education Research Association. They do, however, give some of the flavour of the conference and indicate how the issues addressed differed from those of 14 years ago. The fifteenth conference also contained a number of sessions dealing with research in progress or being conceived. Some of these are noted in the new Research Notes section at the end of this publication.

Richard P. Tisher
Editor

Research in Science Education, 1984, 14, 1-13

STUDENTS' PERCEPTIONS OF HEALTH

Jan Garrard and Margaret Brumby

INTRODUCTION

What does the word 'health' mean to you? Consider the following:

1. Health is the sound condition of a living organism (The Living Webster Encyclopedic Dictionary of the English Language, 1972).
2. Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity (The World Health Organization, 1978).
3. Digestion exists for health, and health exists for life, and life exists for the love of music and beautiful things (Chesterton from Joyce (1982)).
4. Oh health! health! the blessings of the rich! the riches of the poor! who can buy thee at too dear a rate, since there is no enjoying this world without thee? (Johnson, from Stevenson (1958)).

The first two examples are statements of propositional knowledge. The meaning of the statements is derived from the meaning of the biological concepts 'sound', 'condition', 'living', 'organism', etc. The second two examples explain health in terms of the individuals' interests, attitudes, appreciation and values - attributes associated with the affective domain of mental activities.

So what is health? Is it our state or condition as a living organism? Or is it how we feel, what we value, or something that enables us to do things we enjoy? Of course it is both. These views are not mutually exclusive but are two different perspectives. Health is a scientific concept as well as a highly valued personal attribute.

How do students perceive health? This study sets out to explore both the cognitive understanding of the concept of health, and the wider perspectives of attitudes and beliefs. Thus the word 'perceptions' is used in the broad sense of beliefs, opinions and understandings.

Much research in health education is directed towards the implementation and evaluation of programs designed to change students' knowledge, attitudes or behaviour in a specific area of health such as nutrition, physical fitness, alcohol, drugs, etc. Programs such as these have been reviewed recently by Davidson (1979) and Rothman and Byrne (1981).

Very little research has been carried out into students' understanding of the actual concept of 'health', rather, the emphasis has been on selected aspects of health. For example Crawford (1981) superficially surveyed the nutritional knowledge of high school students using multiple choice questionnaires. Goldman and Goldman (1982) explored children's understanding about sex in some depth using clinical interviews.

One of the very few research studies which attempts to explore students' understanding about health in general is the work of Schaefer and his colleagues (1980, 1984a). Schaefer has used word association tasks, written definitions and multiple choice questionnaires to study students' conceptions of health. While we take issue with Schaefer's methdology of data collection and analysis of results, his 'burr model' of a concept has some value. According to this model, a concept has three components: the 'word' (designation, term), the 'logic core' (interpersonal meaning as defined by a scientific community), and the 'associative framework' (a network of personal associations surrounding the scientific part of the concept).

The value of Schaefer's model lies in its recognition of the importance of the associations which people have with a concept. These associations, which are derived from our everyday life experiences, can be cognitive or non-cognitive, and they give concepts their highly idiosyncratic meanings.

Recently there has been an increasing awareness that concept formation and conceptual change do not take place in an affective vacuum. After a decade or so of research based on Ausubel's cognitive learning theory, which largely ignores the affective components of learning, interest in the affective domain is increasing. West and Pines (1983) have argued theoretically that:

> Nonrational components are intrinsic to conceptual change in the individual, and that these should not be excluded in investigations of conceptual change.

Similarly, Head and Sutton (1984) argued that:

> The main omission (from accounts of the logical conditions necessary for an individual to be willing to change his or her mind and thus undergo learning) has been an adequate recognition of the affective elements, that changing one's mind is not a purely cognitive act.

In a recent review of the past 10 years of research in science education White (1983) proposed a teaching/learning model which included an 'attitude trait and personality' factor which was absent from the simple Instruction-Performance model of previous decades.

In the area of health education research Maddock (1983) has surveyed students' attitudes to health and awareness of health issues. He reported low correlations between scores on an attitude scale and on an awareness scale. However, Gauld and Hukins (1980) point out that:

> In many instruments (such as multiple choice questionnaires) used to measure attitudes the "expected" answer is very easy to detect and the response of the subjects can be more influenced by their desire to satisfy the expectations of the research worker or teacher than by the willingness to expose their own attitudes or beliefs.

The primary goal of this study was to apply methods, already demonstrated as being effective (see Brumby, 1984), of exploring students' understanding of the concept health and, of even greater importance, to obtain data indicating why students reasoned the way they did. This necessarily involved exploration of the wider aspects of attitudes and beliefs.

STUDENT POPULATION

Thirty-nine secondary students in Year 10 at a co-educational metropolitan high school in Melbourne and 51 tertiary students from Monash University took part in the study. The secondary students consisted of two complete classes. The tertiary students were the total population of science graduates enrolled in the Diploma of Education course at Monash University and taking at least one of the science teaching methods.

METHODS

Two techniques were used to explore students' understanding. This paper reports the results of two questions, one from the written section (Part A), and one from the

interview (Part B). Part A consisted of two questions requiring written responses which were given in a group session. Both questions were problem-solving tasks designed to obtain divergent answers.

The questions were novel to the students in that they were not drawn from the curriculum of any one subject, but were set in the real world and therefore required the students to draw on their general knowledge and life experiences.

Queston A1

Here is a photograph of a very old lady with her great great grand-daughter. She is well over 100 years old and has therefore lived more than 25 years longer than the average person in Australia.

(a) What factors do you think may have contributed to her long life?

(b) Do you think you will live as long as she has? Why?

Half a page was provided for each of these answers.

Part B was a semi-structured clinical interview. Each interview lasted about 30 minutes and was audio tape-recorded and independently transcribed verbatim. In each of the interview questions a visual stimulus was used both to focus students' attention and to avoid any tension that might arise in a more direct interviewer/student interaction.

Identical wording was used to introduce the question to each student and care was taken not to 'cue' the student in any way. Probing of the student's understanding was limited to noncommital encouragement to continue speaking, such as 'mm', 'yes', 'that's interesting', or 'would you like to say more about that?'

Students were shown a Scrabble board with letters spelling the word HEALTH placed in the centre of the board. Students were asked:

Question B1

If you had a game of Scrabble with a friend, and you started with this word and your friend said 'What does that word mean to you?', how would you go about explaining it?

Analysis of results

Question A1 (the old lady question) and Question B1 (the Scrabble question) have been analysed for their conceptual content. For each question the concepts used by the students were listed and then scrutinized to see if they fell into specific areas or categories. The categories which emerged are shown in Table 1, together with

examples of students' responses in each category. The placement of students' responses in each category was done by three independent judges and any disagreements were discussed and a joint decision taken.

TABLE I

Categorization of students' responses to questions A1 and B1

	Category	Examples
1	Non-specific	Looking after yourself. A state of well-being.
2	Illness	Not sick. Haven't got any diseases.
3	Heredity	Genetic factor. No inherited diseases.
4	Body	Looking after your body. Healthy physically.
5	Fitness	Keeping yourself fit. Doing plenty of exercise.
6	Nutrition	Eating the right foods. The diet we have.
7	Drugs	Don't smoke. Don't drink.
8	Hygiene	Keeping clean. Brushing your teeth.
9	General mental	A state of your mind. Healthy mentally.
10	Will to live	Strong will to continue. Great will to live.
11	Interpersonal	Interpersonal relationships. How you affect other people.
12	Lifestyle	Your whole lifestyle. Time for leisure.
13	Natural environment	Cleaner environment. No pollution.
14	Luck/accidents	Luck. Lower risk of accident.
15	War	High risk of war. World will come to an end.

These categories were grouped into four dimensions of health based on the WHO definition of health given above. The percentage of students who mentioned a concept within each category was calculated and the percentage of students responding in each dimension was also calculated. Because the percentages quoted throughout this paper are percentages of students and not percentages of responses, percentages are not additive.

These results are represented semi-quantitatively in the concept maps shown in Figures 1 to 4. The maps illustrate the concept categories which emerged for each group of students in each of the two questions, as well as the relative importance of the categories. The strength of the line going to each category is an indication of the number of students who gave responses in that category. If fewer than 10 per cent of students gave responses in a particular category this category was omitted from the map. A dotted line indicates that 10 to 19 per cent of students responded in this category, a normal solid line represents 20 to 49 per cent of students, and a broad solid line represents more than 50 per cent of students.

RESULTS AND DISCUSSION

Conceptual content of responses

Figure 1 shows that secondary students described health predominantly in physical terms. Ninety per cent of secondary students mentioned one or more concepts in the physical dimension. The figure is probably 100 per cent if one is prepared to interpret statements such as 'feeling well' and 'looking after yourself' as referring to physical health. In categorizing student responses a minimum of personal interpretation was used. This resulted in the 'general' dimension which appears additional to the dimensions in the WHO definition.

Secondary students strongly associated health with physical fitness (74%) and nutrition (54%). A small number of secondary students mentioned mental factors, but the social dimension of health was absent.

Figure 2 shows that tertiary students, while still describing health in predominantly physical terms, were far more aware of the mental and social dimensions of health.

However, the concepts students used to describe their meanings of the word health (the Scrabble question) are not the only health concepts these students think are important. When students were asked about the influences on health and long life (the old lady question) several new concepts emerged. Figure 3 shows that, for secondary students, while the general and physical dimensions were still important, more students mentioned mental factors - both general mental factors and the new category 'will to live'. The social dimension, which was completely absent in their descriptions of health, strongly emerged, if it is accepted that the new categories 'interpersonal', 'lifestyle', 'natural environment' and 'luck/accidents' belong within the term 'social'. Indeed the WHO does not state explicitly what is meant by the term 'social well-being'.

Figure 4 shows that similar trends emerged when the tertiary students looked at influences on health. The mental and social dimensions were mentioned more frequently than in their descriptions of health. In addition the totally new categories 'heredity' and 'war' were included by the tertiary students. These two categories were absent from the secondary students' responses.

FIGURE 1

STUDENTS' DESCRIPTIONS OF MEANING OF CONCEPT HEALTH - YEAR 10

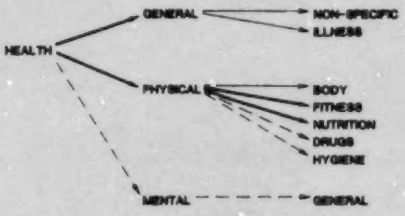


FIGURE 2

STUDENTS' DESCRIPTIONS OF MEANING OF CONCEPT HEALTH - TERTIARY

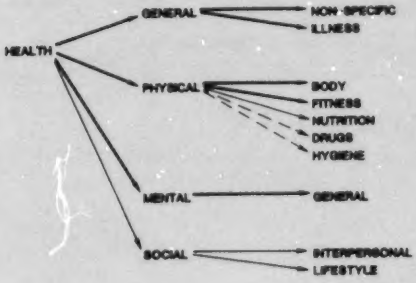


FIGURE 3

STUDENTS PERCEPTIONS OF INFLUENCES ON HEALTH AND LONG LIFE - YEAR 10

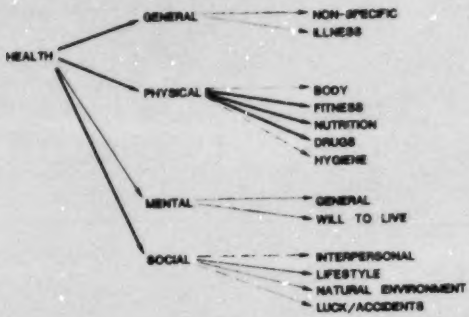
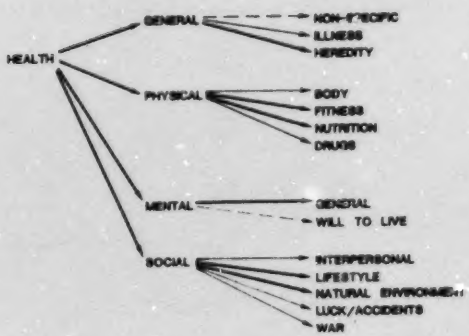


FIGURE 4

INFLUENCES ON HEALTH AND LONG LIFE - TERTIARY



Structure of responses

As well as differences in conceptual content between the two groups' responses, there were also marked differences in the structure of their descriptions. For example, in the physical dimension, secondary students frequently mentioned specific concepts such as 'fitness' and 'nutrition', while tertiary students used more general concepts such as 'physical condition' and 'physical well-being', subsuming the specific concepts of 'fitness' and 'nutrition' under the more general concepts of 'condition' or 'well-being'.

Secondary students' descriptions of health were nearly all simply collections of concepts with little relational language linking them. For example,

> Health - being physically fit and eating the right foods and just being healthy ... I mean - fit and well, yeah, something like that.

Most tertiary students used logical relations to link concepts. For example,

System/part:

> Just how you felt. I'd have to split it into psychological, social, body functions, but I'd just say that I split it up doesn't mean that they're not inter-related.

Cause/effect:

> Smoking impairs physical activity. Obesity causes heart disease.

Qualified statements:

> Not just the absence of illness, but an ability to live life to the fullest.

Superordinate/subordinate:

> It's a word that relates to your well-being - your body health and your mental health.

Referring back to the concept maps in Figures 1 and 2 it can be seen that tertiary students were not only more aware of the mental and social dimensions of health, but they also perceived links between concepts both horizontally (e.g., physical health includes correct diet) and vertically (e.g., physical and mental health are related).

Can we conclude from these results that tertiary students have 'better' perceptions of what health is? Certainly their conceptual content was more extensive and they organized their ideas with greater fluency and with more logical structure. But the cognitive is only one aspect of students' overall perceptions.

Negativity - the illness model of health

Tertiary students were twice as likely as secondary students to include an 'absence of disease' component in their descriptions of health. This is quite sound scientific reasoning. Within traditional scientific method (see Maggee (1973) on Popper), it can be argued that if an organism has a disease or is sick then the hypothesis that the organism is healthy is not supported. Therefore in this sense health can be validly described as having an absence of disease component. Although we would not argue with the logic of such a statement, we might question the different attitudes of students who described health as the absence of disease compared with students who talked only about what health is. Schaefer (1984b) claims that students who describe health as the absence of disease do have a more negative attitude to health. When comparing the disease-oriented associations to health of a student population in West Germany with the health-oriented associations of a similar population in the Philippines he states:

> ... the difference is not due simply to school learning, but to a general attitude towards life and the risks of life which seems to differ remarkably between West Germany and the Philippines.

However the question of positive/negative statements and attitudes is a complex one. For example how would the following statements be classified?

> I [can] have the 'flu and still feel very healthy.
>
> If he's got any diseases he's overcome them and is physically active.

These students are saying, like the world health definition, that health is more than the absence of disease.

On the other hand students can make negative statements without referring to the illness model. For example,

> Not doing all the naughty things like eating fatty foods and all that sort of stuff.
>
> No smoking and drinking.

To these students, health is not doing certain things.

Active/passive descriptions

Another way in which secondary and tertiary students differed was in their use of active/passive explanations. Secondary students tended to describe health as something you do, that is, as a process. For example, 'Looking after yourself'. 'Keeping your body in good shape'. Tertiary students tended to describe health as something that you are, that is, as a state. For example, 'A state of well-being'. 'Being fit'. 'Feeling well'.

Do these differences reflect different attitudes in the conative or tendency-towards-action sense? The consistency of these types of answers is currently under investigation.

Fatalism and pessimism

The questions of positive/negative and state/process are both related to the important issue of whether students believe that their health is their own responsibility or whether they consider that it is the inevitable consequence of factors which are largely beyond their control. The five new categories of responses which appeared in students' explanations of attributes of long life but were absent in their descriptions of health were 'heredity', 'will to live', 'natural environment', 'luck/accidents' and 'war'. Four of these factors (the exception being 'will to live') are beyond individual control. These four factors were mentioned far more frequently by the tertiary students than the secondary students. Also many of the other concepts mentioned by the tertiary students were perceived by them to be beyond individual control. For example in the category 'fitness', the old lady's presumed physical fitness was frequently attributed to 'working hard on the farm' or 'having to walk everywhere', not to a conscious effort on her part to maintain her fitness. Similarly, in the category 'nutrition', the old lady's presumed good diet was attributed to the 'lack of man-made chemical additives' in the food she ate rather than her conscious decision to eat a balanced diet.

In contrast, secondary students accounted for the old lady in terms they had used for themselves in their own lives, for example, 'keeping herself fit', 'having regular meals', and 'eating nutritious foods'. It could be interpreted that tertiary students have a more fatalistic attitude to health than secondary students. This fatalistic or lack of control attitude was implied in many of their responses. However some students stated it quite explicitly, for example:

> No. Factors beyond my control. E.g., accident, war, environmentally induced diseases, hereditary factors.
> No. I do not consider myself as being able to live as long as she has due to the lifestyle that I have inherited
> - Environment - high stress
> - Foods - highly processed
> - Pollution - air/water
> - Dangers - driving a car.

In addition to the question of fatalism is the question of pessimism, i.e., not only will 'what will be will be', but there is the further implication that 'what will be will be bad'. One quarter of secondary students answered 'yes' to the question: 'Do you think you will live as long as she has?' No tertiary students thought that they would live as long as the old lady, and their reasons for answering in this way largely consisted of factors perceived by them to be beyond their control. For example, 'I will have more psychological pressures throughout life.' (categorized under general mental) and 'Fast living of today is difficult to escape from.' (categorized under lifestyle).

CONCLUDING REMARKS

In this study many of the concepts and attitudes emerged from the question based in the real world, rather than through the question which asked students to explain their understanding in their own words. However, the 'explain health' question resulted in good definitional statements with many students articulating links between the concepts they used. Students tended to answer the 'influences on health' question in point form which did not reveal any links they had between concepts.

Students' answers to the 'influences on health' question suggested a degree of fatalism and pessimism which has not been previously identified in health education research. Is this fatalism and pessimism involved in the frequently stated lament of health educators that 'healthy behaviour' does not necessarily result from students knowing what is 'good' or 'bad' for them? If so, how should this be taken into account in health education programs? Further, how should courses be developed which set out the mental and social dimensions of health?

To our knowledge this is the first time such detailed data have been collected about how students think and feel about situations and events which influence their health. The findings reported here support the theoretical arguments (e.g., West & Pines, 1983) that the non-cognitive aspects of learning are important in the whole area of concept formation as well as conceptual change.

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ATTITUDE TO HEALTH AND KNOWLEDGE OF HEALTH ISSUES IN NURSES, HIGH SCHOOL AND PRIMARY SCHOOL PUPILS

Max Maddock, Phil Moore, and Bill Warren

INTRODUCTION

Interest in the general area of human physical and mental welfare appears to be shifting from focus on illness and disease to a concern with health and 'wellness'. As with the focus on ill health the focus on health has brought attention to the significance of lifestyle factors which reflect not only what one knows about healthy living but also the manner in which such knowledge interacts with one's beliefs and attitudes to generate behaviours that are conducive to wellness rather than illness.

This general interest in physical and mental wellness is reflected at various levels from the popular press to the formal inclusion of health as an important feature of school curricula. At the school curricula level for example, the aims of health education curricula typically make reference to knowledge, attitudinal, and behavioural outcomes; (N.S.W. Department of Education, 1981) and health aims reflecting these dimensions are also included in syllabus objectives for subjects such as science as is the case in New South Wales (Secondary Schools Board, 1980).

Specific research projects concerning knowledge and attitudinal factors related to health issues have come into prominence, such as the Reville and Drury (1980) study on cigarette smoking in fourth year school children and the Simons et al. (1982) investigation into health attitudes, knowledge, and coronary risk factors in high school children. Another manifestation has been the appearance of 'wellness workbooks', such as that by Travis (1977). These concerns generate the need for:

(i) clearer conceptualisations of the features and factors of 'wellness', in order that a merely topical or 'faddish' approach might be avoided;

(ii) some attention to the interrelatedness of cognitive and attitudinal factors; and

(iii) techniques for specifying knowledge and attitudes and their interrelatedness in individuals and in the general population or sub-populations.

The present paper addresses the second and third of these needs directly, providing thereby some perspective for the first.

PREVIOUS STUDY

In 1982 Maddock investigated attitude to community and personal health and awareness of health issues in high school pupils in the Hunter Valley of New South Wales. A 24 item Attitude to Community and Personal Health Scale (CPH) and 28 item Health Awareness (HA) scale were developed and administered to a sample of 636 high school pupils from Grades 7-11 in eight schools. Both scales produced good coefficient alpha reliability coefficients. It was found that while attitude became very significantly more negative with increasing grade level (1.05 standard deviations lower in Grade 11 than in Grade 7), awareness increased by 1.7 standard deviations. Zero level correlation between attitude and awareness was found. In most of fifteen classes where CPH was correlated with results of classroom achievement tests in science, the relationship was of zero order or significantly negative.

The study had been carried out because of the clear implications in the New South Wales Schools Board Science syllabus for Grades 7-10, under a heading 'Staying Healthy', that content should be chosen to extend knowledge in the area of bodily systems and their functions in order to affect attitudes and habits 'so that wiser decisions can be made in relation to the development of sound health practices' (Secondary Schools Board, 1980).

THE 1983 STUDIES

Investigation into attitude and awareness was extended to a wider spectrum than high school students by two studies in 1983. The Attitude to Community and Personal Health (CPH) scale and the Health Awareness (HA) scale were administered to 254 hospital nurses and First Aid students in various stages of training, drawn from urban and rural centres of Central to Northern New South Wales. Questionnaires were administered during a 'block' training period conducted by TAFE and were administered as written tests in the same form, and in the same manner, as used with the high school students in 1982. CPH was administered to 328 primary school pupils from Grades 5 and 6 in three schools in the Newcastle area. The results of the three studies with CPH and the results of the nurse and high school studies with HA were compared using t tests for differences between means. The nurse results were analyzed using a cluster analysis based on the item scores from CPH and HA.

For the primary school pupils, CPH was modified in form and administration. Firstly, several items were rephrased and conceptually demanding vocabulary replaced with more appropriate language. Secondly, because reading ability may influence performance on self-report questionnaires with young children (Sunseri

et al., 1983), the modified questionnaire was group administered by reading orally each of the items and their responses twice, while the children followed the text from their own copies of CPH.

SCALE CHARACTERISTICS

Nurses

For CPH, the alpha coefficient was 0.68 compared with 0.77 obtained from the 1982 high school sample, with scores ranging from 72-45 out of a possible 72-24 range, with a mean of 62.3 and standard deviation of 4.8. For HA, alpha was 0.82, compared with the 1982 high school result of 0.80, with a mean of 24.8 and a standard deviation of 3.5 (see Table 1).

Primary School Pupils

The alpha for CPH scores obtained from the primary school sample was 0.83, strongly satisfying the Nunnally (1969) criterion. The scores ranged from 72-26, with a mean of 61.4 and standard deviation of 7.27 (see Table 1).

TABLE 1

CPH

Scale Performance

	N	Score Range	Mean	S.D.	Alpha
Nurses	254	72-45	62.3	4.8	0.68
Primary	328	72-26	61.4	7.3	0.83
High School	636	72-36	59.3	6.35	0.77

COMPARISON OF HIGH SCHOOL, NURSE, AND PRIMARY SCHOOL RESULTS

The highest mean score for attitude was obtained by the nurses (62.3), with the primary school mean next (61.4) and the high school mean the lowest (59.3). Tests for comparability of variance (Winer, 1971) showed that the three groups had different variances. Appropriate t tests for such groups (Winer, 1971) were calculated which showed that the nurse sample mean was significantly more positive than the primary sample mean, which was in turn significantly more positive than the high school mean (see Table 2).

TABLE 2

CPH
Comparison of Means

	N	Mean	Difference in Means	S.D.	t	df	p<
Nurses (N)	254	62.3		4.8			
			(N-P) 0.9		1.8		0.05
Primary (P)	328	61.4		7.3		561	
			(P-H) 2.1		4.5		0.005
High School (H)	636	59.3		6.4		579	

Although the nurse-primary school difference is statistically significant, the magnitude of the difference is quite small, less than 1 per cent of variance in CPH scores being associated with membership of the two groups, based on the point biserial correlation value of .07 calculated from the t ratio and the degrees of freedom (Cohen, 1965). The primary-high school group membership, however, is a stronger effect accounting for about 3 per cent of variance (point biserial correlation of 0.18).

In the case of the Health Awareness Scale (HA) the nurse sample mean of 24.8 was 7.9 scale points (about 2 standard deviations) higher than the 1982 high school mean of 16.9, indicating that the nurse sample was considerably more knowledgeable and aware concerning health issues than the high school pupils. The t ratio of 97.3 (df 643, p<.001) produced a point biserial correlation of 0.97 (Cohen, 1965) indicating that about 94 per cent of the overall variance across groups is associated with group membership. The comparison is summarized in Table 3.

TABLE 3

Health Awareness (HA)
Comparison of Nurses and High School Pupils

	N	Mean	S.D.	Difference in Means	t	df	p<	rpb
Nurses (N)	254	24.8	3.5					
				7.9	93.5	643	.001	0.97
High School (H)	636	16.9	4.8					

CPH-HA correlation for the nurse sample was 0.18, significant at the 0.05 level, but represents only about 3 per cent of common variance between the two scales and is thus a very weak relationship. This compares with the -0.3 correlation found for the high school sample in 1982 and is consistent with relationships found between knowledge or awareness and attitude in the studies carried out by Maddock into attitude to conservation (Maddock & McDonald, 1982).

CLUSTER ANALYSIS: NURSES

The nurse data was subjected to a cluster analysis (Youngman, 1976) using the item scores from CPH and HA as clustering variables for program CARM. Three meaningful groups of nurses were revealed, which were then subjected to descriptive analyses based on background data and on test scores for CPH and HA.

A group of 121 subjects was identified in which the attitude mean (66.1) was about 0.8 standard deviation higher than the mean of the whole sample (62.3), and 1.5 standard deviations (just over 7 scale points) above the means of the other two clusters (58.8 and 58.9 respectively), which contained 118 subjects and 15 subjects. The level of awareness (means 25.7 and 25.2 respectively) was about the same for both of the first two clusters, but for the minority group of 15 was low (6.6 scale points, or 1.9 standard deviations) below the level of cluster 1. The characteristic profiles of the three clusters compared with the characteristics of the total sample are summarized in Figure 1. The cluster which can be described as highly positive in attitude and highly aware (cluster 1) was characterized by a high proportion of urban subjects (66 per cent compared with 54), of females (86 per cent compared with 81), of general training (91 per cent compared with 87), and of first course trainees (92 per cent compared with 87). The cluster which might be described as more negative in attitude, but equally as aware as cluster 1, was characterized by a higher proportion of rural trainees (53 per cent, compared with 30 per cent for cluster 1 and 43 per cent for the total sample), by having the highest percentage of males (19 per cent, compared with 10 per cent for cluster 1 and 14 per cent for the whole sample), with a lower percentage of general trainees (75 per cent, compared with 91 per cent for cluster 1 and 83 per cent for the whole sample).

Cluster 3 consisted of a small minority of 6 per cent of the whole sample which contained predominantly rural trainees (60 per cent compared with the samples 43 per cent), who were much younger people (73 per cent under 20 as compared with 58 per cent for the sample). It can be seen from Figure 1 that the most aware subjects in

this group were significantly less aware than the least aware of either cluster 1 or cluster 2. It can also be seen from the figure that there is very little overlap between the most positive attitudes in cluster 2 and 3 with the least positive attitudes for cluster 1.

DISCUSSION

The Attitude to Community and Personal Health (CPH) scale, originally developed for use with high school students, has been shown to be a viable and potentially useful research instrument using a wider population, including adults (nurses) and primary school pupils. Although the form used with primary pupils underwent minor modification of wording to suit primary language and concept level and although it was administered by a group-verbal technique it was essentially the same instrument. Results of research in Papua New Guinea with an attitude scale which pioneered the scale construction technique used in developing CPH, using concrete incidents and choices of specific behavioural alternatives, (Maddock, 1982) indicate that written tests, group verbal or one-to-one interviews produce closely similar results.

The finding that the primary school attitude mean was more positive than that of the high school sample is consistent with the pattern found in the 1982 study (Maddock, 1983) of a shift towards the negative end of the attitude continuum with increasing grade level. It would be reasonable to expect that nurse attitudes would be more positive than other members of the community.

The weak attitude-awareness relationship, exhibited in the nurse study, is also consistent with findings in previous studies by Maddock (e.g., Maddock & McDonald, 1982). Apart from the correlation of 0.18, this is further emphasized by the differences between the nurse and high school results. A statistically significant, but relatively small difference in a more positive direction was found for CPH, but a huge difference (about 2 standard deviations) was found in the case of HA, nurses being vastly more aware of health issues than the high school pupils. The results of the cluster analysis also emphasize the inconsistency of the knowledge-attitude relationship, with one group having both more positive attitudes and a high level of awareness, one group less positive attitudes and a high level of awareness and a third group being both less positive and being very much less aware of issues.

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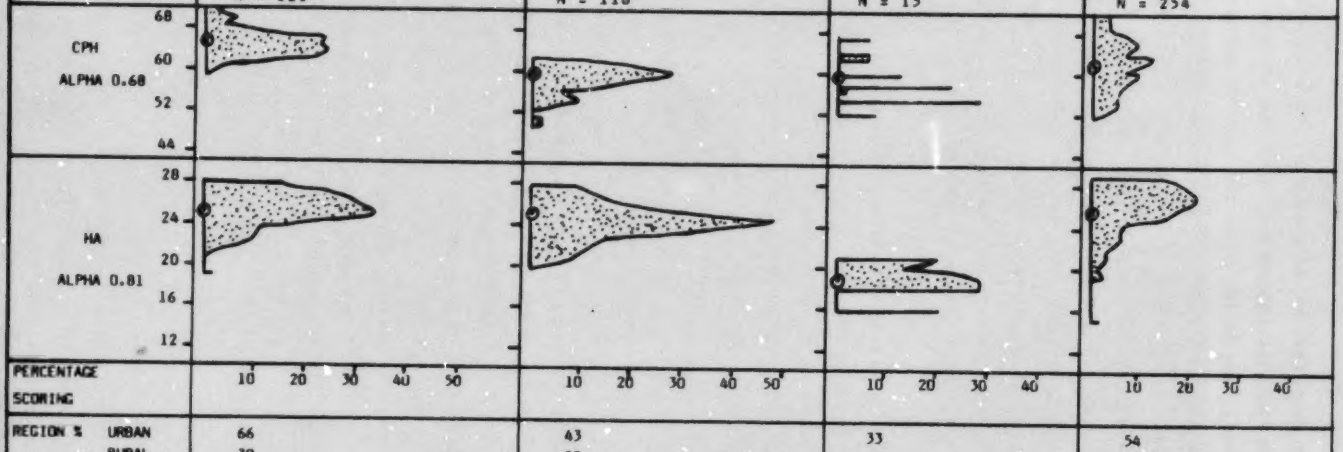

		CLUSTER 1 N = 121	CLUSTER 2 N = 118	CLUSTER 3 N = 15	TOTAL SAMPLE N = 254
REGION %	URBAN	66	43	33	54
	RURAL	30	53	60	43
AGE	U 20	58	57	73	58
%	21-25	19	20	13	19
	26 +	9	19	14	15
SEX %	M	10	19	13	14
	F	86	76	80	81
TYPE %	GENERAL	91	75	80	83
	OTHER	9	25	20	17
TRAINING 1ST COURSE		92	83	80	87
%	OTHER	8	17	20	13
YEAR OF TRAINING					
%	YR 1	47	43	80	47
	YR 2	14	11	0	13
	OTHER	39	46	20	40

NOTE: Discrepancies in summing to 100 due to failure of some subjects to provide information.

FIG.1 Profiles of clusters from cluster analysis of the nurse sample, 1983, giving means (circled point), score distributions and background information.

The observations presented provide both a perspective and a practical instrument for concerns with health and wellbeing. Moreover, it is apparent that 'mere knowledge is not enough': that is, knowing that something is dangerous, 'bad for you', or more-generally not conducive to wellbeing might not be enough to ensure appropriate behaviours (the phenomenon of the physician who smokes cigarettes is well known).

This last observation may be especially important in the context of the preparation of health professionals like nurses where equal attention to attitudinal factors as to knowledge may be important. Equally the provision of knowledge in school curricula may not be sufficient to promote the desired behaviours if attitudinal factors are not addressed. The negatively directioned shift in attitude from primary to secondary school may also point up the need for increased attention to milieu factors in promoting or destroying early positive attitudes.

The results of the cluster analysis suggest that such factors as regional location of place of work are interrelated in influencing knowledge and awareness, pointing to the need for further research which looks beyond the formal school or training curriculum. Further analyses are to be carried out with the primary school data to examine sex, grade, and socio-economic status variables and their interaction. Data has been collected by Maddock in 1983 under a Menzies Foundation Grant from high school pupils in Tasmania, Victoria, and New South Wales which looks into health behaviour factors such as eating, exercise, smoking and drinking habits, family, community, and media influences in addition to educational background and socio-economic factors, to further explore the interactions of other variables.

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WHAT DO HIGH AND LOW ACHIEVERS REALLY THINK OF THEIR LEARNING ENVIRONMENTS?

Richard Tisher

BACKGROUND

During the last 15 years several writers (Delamont, 1976; Keddie, 1971; Stebbins, 1970) have suggested that researchers should, more often than is the case, gather information from teachers and pupils about the definitions or meanings they give to their learning environments. There are grounds for doing this. Teachers and pupils play influential roles. Teachers, for instance, control and monitor the knowledge that is made available to pupils and their perspectives on what should be made available is indicative of the view they have of their pupils (Keddie, 1971). Also, what they say and do convey attitudes and values to pupils. Similarly, pupils convey attitudes to each other and to their teachers - attitudes and values that in turn affect teachers' perceptions of them and behaviour towards them. To understand more clearly what effect various teaching strategies have it is important to gain teachers' and pupils' perceptions about their teaching-learning environments.

A number of researchers have tapped teachers' perceptions through interviews or pupils' perceptions through questionnaire, e.g., the Learning Environment Inventory (Anderson, 1971). Few have, in a concerted way, gathered data from pupils by interview, although there are several recent significant reports about researchers 'listening to pupils' (Good, 1981; Weinstein & Middlestadt, 1979).

As part of a larger study on teaching strategies in science and social science classrooms (Tisher, 1981) it was decided to ask high and low achieving pupils what they thought about their learning environments. High and low achievers were chosen since it was thought that they would hold markedly different views about their classes and about their treatment in them.

PROCEDURES

There were 14 Year 9 classes (7 science, 7 social science) in the investigatory sample - each one using novel curriculum materials from either the Australian Science Education Project (ASEP) or the Social Education Materials Project (SEMP).

Each class was observed and video-recorded on about six occasions, pupils responded to pre- and post-criterion tests, and completed the Learning Environment Inventory, all teachers were interviewed about the curriculum materials and 84 pupils were asked about their perceptions of their learning environment.

Two procedures were followed to obtain pupils' perceptions of the learning environment. First, four high and four low achieving pupils were selected from each of the investigatory classes according to their scores on the post-criterion tests. Their scores on 12 behaviour measures and 26 perception measures (from the LEI) were then used in a series of analyses of variance to determine whether there were any significant differences between high and low achievers and between science and social science pupils. A few were obtained. For example, compared to the high achievers the lows perceived their learning environment as more difficult, allowing less initiation, little opportunity for active participation, yet requiring them to summarize and explain more often. There were some differences between the science and social science classes with respect to having to cram and work at a fast pace, but these features appeared to be artifacts associated with the nature of the curriculum materials. The social science ones allowed greater freedom and flexibility.

In the second procedure the teachers were asked to designate six pupils in their classes whom they considered to be the most and the least able - three in each category. Of the 84 so designated, 82 were interviewed by the researcher and five experienced, trained assistants. An interview schedule was constructed to guide each interviewer and to guarantee that comparable sets of questions were directed to the pupils. Information was gathered on pupils' evaluations of the purposes of lessons, the curriculum materials, who or what helps them learn, the teacher's attitude to teaching and their significant others (e.g., friends and teacher). These features include those advocated by Stebbins (1970).

All interviews, which lasted about 20 minutes, were conducted in the schools, prior to the administration of the criterion post-tests. Each interview was recorded, transcribed and analysed by the researcher and two assistants. They identified prevalent themes, noted differences in the responses from the more and less able pupils, and discussed and compared the summaries they had compiled. Subsequently the researcher synthesised the information - parts of that synthesis are presented in the following section.

THE PERCEPTIONS OF THE HIGH AND LOWS

(a) about school

There were a number of comparable themes among the able and less able pupils. For example, school was a place that had to be tolerated, it wasn't exceptionally exciting and sometimes it was a little boring, it wasn't outstandingly bad and anyway you needed schooling to get a job! As one pupil said:

> Oh, well, well, I'm not old enough to go to work so I've got to stay at school. But if I'm going to get a good job, I've got to get a good education - so I'll have to stay - gotta get education, so that's about all. I stay for that reason.

Pupils indicated that classes didn't motivate them to a great extent, and that they had to learn things the teacher told them to learn. They did not feel that the learning tasks belonged to them and they were resigned to that situation. A greater number of the more able pupils than the less able expressed satisfaction with their schooling, and were more articulate in expressing what they had learnt in lessons.

(b) about friends

One of the best features of their learning environment for most pupils was the fact that they had friends at school with whom they could socialize. Their friendships seemed to compensate for the low motivational characteristics of lessons. Pupils also felt their friends could help them learn - although they were realistic about the roles that teachers and books could also play. In fact they had an eclectic view about who or what helps you to learn. One pupil expressed the situation as follows:

> ... bit of a mixture. Sometimes if you just listen in to kids in class and what they think, well then you can get a lot of ideas too and it helps you. You can get good ideas from booklets as well, because the information's already there.

Several of the more able pupils, more so than the less able ones, indicated that they didn't need much help from anyone with respect to learning things. One pupil expressed the fact by saying 'there never is anything I don't understand ... I just learn it'. But even the more confident, able pupils who had a very close friend, said that they delighted in that friend's help.

(c) about teachers

Generally the able and less able pupils perceived most teachers as helpful and

they 'guessed' that most of the things they were taught were important. They stated, however, that they could not readily recall the things that they had been taught in the lessons of the past few weeks (i.e., those lessons which were video-recorded).

With respect to teachers' management strategies and, by implication views about teaching, the respondents noted that teachers tended to criticize pupils when someone interrupted the flow of a lesson by whispering 'making a noise', or 'mucking up'. The pupils thought that teachers would react to anything which stopped the steady 'business as usual' flow of the lesson plan. This perspective has been documented by others (e.g., Borko et al., 1979); in research on teacher decision-making. The respondents also thought that boys, more so than girls, were the ones 'picked on' by the teacher for causing disruption.

Although some pupils said they thought the teacher regarded them as pests because they 'mucked about', by and large, what the teacher thought about a particular pupil was not clear to that pupil. Now, it may be that the interview question, 'What does your teacher think of you?' was too difficult since pupils did not have the skills to evaluate their teachers' perceptions of them. On the other hand, it may well be the case that teachers do not often declare what they think about pupils. Even the teachers' non-verbal behaviours were, apparently, not communicating clear messages about the teachers' attitudes towards pupils.

(d) about disenchantment

Although there were, on average, comparable themes among the able and less able respondents which indicated that school had to be tolerated and was motivationally a lukewarm place, there were specific cases of great satisfaction as well as great despondency. The sad cases occurred in the less able group. Consider this section from a transcript where a less able pupil describes the feelings and attitudes of some of his peers.

Interviewer:	What do your other friends think of you?
Pupil:	What they really think of me? Well ... they think that I'm a ... well, seeing that I'm Greek, they think I'm a greasy wog: that I'm a lower class than them and that I'm an idiot.

Some of the less able also perceived school as a harsh, boring, prison-like place as the following two excerpts indicate. The first begins with a pupil's response to a question of whether he and his friends have similar ideas about school.

Pupil: Most of us don't like school.

Interviewer: Why is it they don't like school? What do you think would be the reasons?

Pupil: Umm ... I think that it's just that school bores a lot of people and we seem to think that what we're being taught isn't very exciting - it doesn't interest us at all. So, we tend not to try.

Interviewer: Mmmm.

Pupil: That's mainly what it is.

The second, from another pupil, was in response to the question, 'What do you like least about school?'

Pupil: Oh, I suppose you've got to go here most of your life when you're young, sort of, you've always got to come. You know what I mean - sort of like a prison in some ways. You've always gotta wake up in the morning and get here, and stuff like that. It's probably what I don't like the most - goes on every day.

Regarding their teachers most of the less able thought they were 'all right' but a few were clearly affected by perceived hurtful treatment handed out to them, and some of their friends, as the next two excerpts indicate. With respect to the first one, the pupil has just said that all her teachers have different personalities, and then she continued with:

Pupil: ... our maths teacher is a 'dirty old grouch' ... the science teacher is a funny sort of bloke ... and the typing teacher - I'm having a lot of trouble with him at the moment.

Interviewer: Are you?

Pupil: Yeah. He's ... oh ... he sort of likes to hurt people.

Interviewer: How?

Pupil: Yeah - mm, with words. Yeah, and he sort of likes to get on top ...

The second excerpt followed a comment that the science teacher can be nice and explain things, but,

Pupil: ... if you've been a pest or something he doesn't like that and I don't blame him. But you know, he could stop talking to you for the whole lesson, or put you in a corner, or do something, like a baby.

Interviewer: You don't think that's right?

Pupil: No. No. Nobody does ... Yeah ... makes us sick.

To recapitulate: the interviews with a selection of high and low achieving pupils (according to teachers' ratings) revealed that they tolerated school, regarded lessons as lukewarm motivationally, believed their teacher helped them learn even though they couldn't readily recall what it was they had learnt and enjoyed socialising with their friends. The fact that the highs and lows held comperable perspectives contrasts somewhat with some recent findings by Good (1981). The fact that there were some specific cases of pupils who found school oppressive and prison-like, teachers being hurtful and peers who regarded them as idiots, was a matter of concern.

AWARENESS ABOUT THE LEARNING ENVIRONMENT

The findings from the interviews can be interpreted to indicate that, overall, the learning environments in schools are adequate and tolerable even though somewhat boring. This applies even when novel, self-paced curricula are used. The responses obtained from the high and low achievers appear to be normal ones for Year 9 pupils and so there is no compelling case for educators to be worried and to take some action. On the other hand, the findings reveal that although a proportion of pupils find school satisfying or adequate in a number of respects, there are some pupils who do not find it so - they are disenchanted with their schooling, or their teacher, or their peers. The findings can be interpreted to indicate all is not well in the learning environments and that some things must be done to help the disenchanted pupils. Before help is given, however, teachers need to know who requires it and what kind of help should be given. In other words teachers need to know what is going on in the schools' learning environments.

Unfortunately, teachers, for numerous reasons, do not always know in reasonable detail what is going on in their classrooms and what kinds of effects they are having on <u>all</u> their pupils. Certainly that appeared to be the case in the project from which the preceding data came (Tisher, 1981) - there teachers were not aware, for example, of the proportions of pupils who found their learning environments lacking stimulation or excitement. There have been several attempts in recent years to show teachers how they can learn more about their teaching and how they can monitor adjustments to their teaching style (Smyth, 1983; Tisher, 1983). These efforts have involved pairs of teachers collaborating together to gather data about each other's teaching so that

the one to whom the data applies can evaluate what has occurred and when appropriate make changes. These collaborative efforts should be fostered to a greater extent than is now the case. Were that to be done, there would, it is predicted, be significant changes to the school learning environments and hopefully fewer disenchantments.

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A COMPARISON OF STUDENT THINKING IN A MATHEMATICS AND A SCIENCE CLASSROOM

John Edwards and Perc Marland

INTRODUCTION

The research reported in this paper was undertaken to investigate the thinking of four grade eight students in their mathematics and science classrooms. During an earlier study (Edwards & Marland, 1982), students suggested that contextual variables, such as the particular subject area being taught, coerced different thinking on their part. Mathematics was specifically mentioned as one area where students believed that more intensive information processing commonly took place. This study was designed to reveal the in-class thinking of students in the subject areas of mathematics and science and thereby to allow some comparisons to be made.

The study was conducted within the mediating process paradigm (Doyle, 1977) in which students are represented as active agents in their own learning, directing, monitoring and, where necessary, redirecting their own mental efforts. Accepting that the learner determines the 'received lesson' just as much as the teacher seems a fundamental premise in better understanding the teaching-learning process.

METHODOLOGY

Access to students' thinking during classroom instruction was obtained using a post-lesson interview technique, with recall of in-class thinking being stimulated by means of lesson videotapes. This stimulated-recall interview technique (Clark & Yinger, 1979) has been widely used in process-tracing research to study the mental functioning of people in a range of environments.

Four grade eight students from a moderately large independent secondary school in a provincial city in Queensland participated in the study. Each was chosen by means of a preliminary interview from a cross-sectional group nominated by the two teachers involved, one in maths, the other in science. Criteria used in the selection included expressional clarity, openness, ability to articulate their thinking, and willingness to participate.

Three lessons were videotaped in each subject over a period of one week, with two cameras being used to produce a split-screen recording. One camera focussed on the teacher, the other on the four students and their near neighbours.

Stimulated-recall interviews were held immediately after each lesson, involved one student at a time and one of the two researcher/interviewers, and were each of approximately forty-five minutes' duration. Students were asked to recall all in-class thinking as fully and accurately as possible, with anonymity and confidentiality assured. Each interview was audiotaped, then transcribed for subsequent analysis.

The teachers involved were the regular maths teacher and science teacher for the class. All data were collected in the school setting in regularly time-tabled lessons and rooms, and the teachers were asked not to consciously vary their regular or planned approaches to the lessons. The only disruption was that caused by the presence of the cameras and the technician.

THE LESSONS

MATHEMATICS. Almost all of the time in the three lessons involved the teacher explaining mathematical problem-solving techniques and going through problems on the blackboard. Students were questioned regularly and there were whole-class discussions. The last third of lesson 2 involved students doing problems on the board while the teacher moved around discussing issues with the whole class, small groups or individuals.

SCIENCE. In lesson 1, after a brief introduction, the teacher demonstrated from the front the procedures for using a microscope. The students followed on their microscopes, discussing, answering questions, listening to explanations and drawing diagrams of the microscope. The teacher gave individual remediation towards the end of the lesson. After a brief revision, lesson 2 involved the students studying cheek cells under the microscope. The teacher moved around the room working with individuals or pairs of students, occasionally drawing whole class attention to particular points. The lesson was rounded off by the teacher highlighting important points that had arisen. Lesson 3 was a continuation of lesson 2.

THE STUDENTS

All four students were between 13 years and 13 years 7 months and thought both teachers were good teachers with whom they related well. Susan rated herself in the top third of the class academically, while the other three felt they were in the middle third. Below is some other brief background information:

Susan (Student W). Science is her third favourite subject, maths is eighth. She rates science as her fourth or fifth best subject, maths as her first or second best. She likes school and wants to do well because it makes her feel good about herself. She makes notes to help her learn; likes having teachers and friends to ask about problems, but only after trying herself first; cannot concentrate with noise around and is easily distracted.

Penelope (Student X). Science is her seventh favourite subject, maths is first or second. She rates science as her fourth best subject, maths as her third best. She wants to do well at school and gets annoyed if she doesn't. She gets impatient easily and prefers to 'get in and do things'; often daydreams in class; has to really listen and concentrate or 'I don't take it in'; and feels she learns more by making notes to which she regularly refers.

Mario (Student Y). Science is his third favourite subject, maths is his favourite. He rates science as his best subject, maths as his second best. He is very motivated to do well. He focuses on things he knows will be in the test; often gets frustrated in class but perseveres until he gets things right; regularly questions the teacher; notes down important things and studies them hard; and doesn't mind being called 'teachers's pet'.

Paul (Student Z). Science is his second favourite subject, maths is third or fourth. He rates science as his fourth or fifth best, maths as one of best three. He wants to do well as he has always been near the top, but is worried that he has slipped from primary. He prefers doing things to being told about them; works quickly so he has little homework; regularly uses repetition and practice; and prefers to do his own work then get individual help.

DATA ANALYSIS

The preliminary analysis of the typed transcripts of the stimulated recall interviews was performed by two research assistants. Both were trained in the use of a coding sheet based on the constructs developed in the first phase of this research (Marland & Edwards, 1982). One assistant coded students W and X, the other coded students Y and Z. This crossed over the interviewing pattern of the researchers, where one interviewed W and Z, while the other interviewed X and Y. Joint codings and discussions were used during the training phase to enhance validity and reliability. During the actual coding regular checks were made by one of the researchers.

This paper summarises the data at a broad, general level. What follows are the major trends and issues to emerge from the data, fine-grained analysis is not attempted. Because of the limited size of the study the data can only be seen as illuminative and not as generalisable.

RESULTS AND DISCUSSION

Student perceptions of subject differences

All four students considered mathematics to be more demanding than science, but none could clearly describe or explain in any detail specific differences in their thinking in the two subjects.

Maths was considered to involve more constant thinking, more intense concentration, more time-consuming work, more following the book, more 'working out' and more writing. In maths 'It's very still ... there's hardly any movement or talking going on ... you've got to get down to it'.

Science was considered to be more practical, to involve more doing experiments, more working in groups, less reliance on the book, more application of knowledge in experiments, and more careful listening to instructions.

Subject Comparisons as Revealed by Interviews

Tables 1 and 2 report the major comparisons to emerge from the interview data.

Table 1 reports specific incidences for each student of particular behaviours as reported during interview. The three areas covered are:

- use of a learning process: where the student thinking is learning-oriented;
- reaction to teacher question: where the question elicits a clear behavioural or verbal response;
- student interaction with neighbour: whether or not it is learning-oriented.

While individual results vary, the overall trends are clear. Students reported many more incidences in maths lessons of using learning processes, and more involvement with teacher questioning, while more interactions with neighbours occurred in science lessons. The latter two trends are in keeping with the different teaching styles in the two classrooms, the former is discussed in the next section of the paper.

Table 2 reports the general characteristics of student thinking reported in the interviews. The constructs used are those described in an earlier paper (Marland &

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TABLE 1

Specific Incidences of Behaviours Reported in Interviews

Student	Use of Learning Process		Reaction to Teacher Question		Interaction with Neighbour	
	Maths	Science	Maths	Science	Maths	Science
W	12	3	12	5	14	16
X	11	3	12	11	8	33
Y	23	11	14	12	3	9
Z	27	12	22	9	4	14
Total	73	28	60	37	29	62

TABLE 2

General Characteristics of Thinking Reported in Interviews

Student	Relevance to lesson (%)			Focus of Thought (%)			Attention (%)					
	Overall	Maths	Science	Overall Priv.:Mbr.:Wider	Maths Priv.:Mbr.:Wider	Science Priv.:Mbr.:Wider	Overall Tuned In	:Monitor:	Tuned Out	Maths Tuned In	:Monitor:	Tuned Out	Science Tuned In	:Monitor:	Tuned Out
W	87	82	91	20:28:52	30:17:53	11:37:52	72:11:18			79: 4:21			69:17:14		
X	77	84	72	15:29:55	9: 9:81	19:42:40	64:20:15			74:21: 6			58:30:22		
Y	92	93	92	34: 9:58	38: 5:57	30:11:51	82: 6:12			83: 2:15			82: 9: 9		
Z	84	82	86	35:14:50	44:12:45	26:17:56	72:15:12			65:19:15			81:10: 9		
All 4	85	85	85	26:20:54	28:11:61	23:27:50	73:13:14			74:12:14			72:14:14		

Edwards, 1982). The first is a relatively crude index of the proportion of lesson-relevant thinking, calculated from the proportion of interview segments dealing with lesson-relevant thinking. The second deals with the focus of student thought: 'priv.' is the 'private inner-world' of the student' 'Nbr' is interactions with the neighbour; and 'wider' are wider classroom events involving the teacher and/or other students. The third relates to student attention: whether the student was tuned in to the lesson, was tuned out, or was monitoring the lesson while doing something else (relevant or irrelevant).

Table 2 highlights the idiosyncratic nature of student thinking and the complexity involved in attempting to isolate clear trends. Gross figures such as those reported here in many ways mask the degree of complexity. The periods of attentiveness and particular focus seldom coincided for any two students, let alone all four, resulting in an overwhelmingly complex array of attention patterns. Table 2 reveals a very high incidence (85%) of reported lesson-relevant thinking, with mainly minor variations between subject areas.

The students in this study reported more frequent focus on wider classroom processes than on their neighbour or their private thoughts. With respect to general subject differences: thinking was more commonly focused on interaction with the neighbour in science than in maths, while focus on wider classroom processes was more common in maths than in science.

On average students were more frequently (73%) tuned in to the lesson than monitoring the lesson (13%) and tuning out (14%). While there were differences for individual students, overall there was little difference between the subject areas.

Although it is tempting to pursue the individual patterns of focus and attentiveness this has not been done in this paper.

By comparing these data with the data generated from the Grade 11 biology students in an earlier study (Edwards & Mariand, 1982) an interesting picture emerges. The Grade 8s reveal much more lesson-relevant thinking (85% cf 25%-60%) as well as being 'tuned-in' for much more of the time and being more involved in whole class processes. These trends fit the impressions of many teachers about the general differences between junior and senior secondary students.

Mental Processes

Earlier studies with Grade 10 and 11 students (Marland & Edwards, 1982) identified four categories of mental processes used by students: interpretive, learning, metacognitive, and deception. Interpretive processes are those used for operating effectively and appropriately in the particular classroom. Learning processes are those where the student thinking is learning-oriented. Metacognitive processes are those mental activities in which students think about their own thinking. Deception processes are those students used in order to deceive their teachers. In this study, approximately 80 per cent of the mental processes reported by students were learning processes. Metacognitive processes were negligible and deception processes were under 10 per cent.

When compared with the Grade 10 and 11 students, the major difference was the low frequency of deception strategies with the Grade 8 students. The Grade 8 students were much more open with their teachers, much more trusting and respectful of their teachers, and much less inclined to become involved in complex interpretations of classroom interactions. Indeed both interviewers found the openness and relative naivety of the Grade 8 students a marked change from the complexities of the older students. Their open trust of their teachers is exemplified by Paul's refusal to try solving problems by 'his own' methods: 'The book's saying to do it, so that's what someone wants us to do. If Mr Holden didn't want us to do that then he wouldn't tell us to do what the book says'.

Metacognitive processes were almost completely absent in this study as they were for the older students. This again implies that students seldom reflect on their own thinking. The apparent success of some programs designed to teach thinking skills (Edwards & Baldauf, 1983) suggests the need for more research into whether improving students' metacognitive skills would lead to improvements in student thinking and learning.

If the differences revealed here between Grade 8 students and Grade 10 and 11 students were confirmed by a more comprehensive study this would raise many interesting issues. For example: are the changes the inevitable result of growing up in our society or is it that secondary schooling brings about these changes?

The major difference between maths and science in this area was that revealed in Table 1, the much higher reported usage of learning processes in the maths classroom. This fits in well with the students' perception that maths involves more constant thinking and more intense concentration.

Student Activity

A simple count was taken of the different types of student activity, both physical and mental, reported in the two classrooms. There was a marked difference in the range and frequency of student activities elicited. The students reported almost three times as many different types of student activity in the science lessons as in the maths lesson. The total number of reported activities was five times as great in science as in maths.

The experiments in the science classes account for the majority of activities, and for the diversity. Also the greater freedom of activity available in the science lessons provided the time, the opportunity and often the motivation for the student to think and act more freely.

Preferred Learning Modes

Throughout the interviews the students suggested a wide range of preferences for particular ways of operating in the classroom. In general the students preferred to have less whole class instruction, more individual and positive interaction with the teacher, more doing and less writing and talking, more 'getting on with the work', and a clearer sense of direction in the lesson.

Role of the Neighbour

Interactions with the neighbour varied from student to student and lesson to lesson, but generally two out of every three interactions with the neighbour were directly lesson-relevant. Science involved more than twice as many interactions with the neighbour as maths. The types of interactions with neighbours in science lessons included: comparing work, challenging each other's answers, helping in experiments, dividing tasks and co-operative work, discussing results, relaxing each other, reassuring each other, explaining things to each other, and discussing answers to teacher questions. In maths the main interactions were: comparing answers, explaining to each other, competing with each other, and helping when in trouble with teacher. While the science lessons at times allowed and encouraged interactions with the neighbour, many productive interactions were still occurring in spite of the teacher. This reinforces the belief from the earlier study (Marland & Edwards, 1982) that the potential of co-operative student learning is largely overlooked in the secondary classroom.

Mental Responses to Teacher Questions

From the earlier study (Marland & Edwards, 1982) seven general categories of response types were developed: academic, emotional, attributive, evaluative, deceptive, manipulative, and non co-operative. In this study 58 per cent of responses

were academic (thinking about information related to the question and/or the answer), 21 per cent were emotional (expressing feelings about the teacher and self), 10 per cent were non co-operative, eight per cent were attributive, and three per cent were deceptive. There was almost no difference across subject areas except for an increased proportion (7%) of emotional responses in science against a corresponding decrease in attributive responses. This difference mainly reflects a slightly greater degree of expression of feeling about self in the science classroom as opposed to focus on the teacher and his intentions in the maths classroom.

As was reported in Table 1, there were approximately twice as many questions responded to by the four students in maths lessons as in science lessons. However, a count of the questions asked in the two classrooms revealed 113 questions in the maths lessons and 37 questions in the science lessons. So, even allowing for the 'sampling error' of the interview technique, it appears that a greater proportion of the questions in science than in maths elicited individual reported student reactions.

Teaching Aids

The reaction to teaching aids was common across subjects. The major comment was that the students liked teachers to use the blackboard. The main reason was that this allowed the students to read at their own pace and to revise if necessary. Reactions to other aids varied from suggestions that they are 'just cheats for lazy teachers' to some measure of support. OHP's got second highest support, with slides, films, wall charts, and models getting mixed support. There was strong support from some students for the activity-based ASEP units they had been using in science.

Validity

The four students all felt that apart from some tenseness on the first day, the lessons and student behaviour were fairly normal. They considered thestimulated recall technique to be a good one: 'I don't know that there would be any other way that you could remember what you were thinking then', and suggested that their thoughts revealed in interviews were very close to their actual thoughts. All rejected the concept of observer inference strongly: 'You might be going like that, looking asleep, and you might be having full concentration on him'. One student reported in the fifth interview that he was getting sick of the disruption to his program 'but because there's only one to go I'll stick it'. They all felt that as a group of students in the class they were 'fairly average'.

Susan found that the recording of herself and her neighbour aided recall the most. Paul felt that the recording of the teacher helped most.

CONCLUSION

This study represents the second phase of a major research project. Much of the data has confirmed what emerged in the first phase (Marland & Edwards, 1982), particularly the idiosyncratic nature of student functioning and the complexity of the teaching/learning process.

In the mathematics and science classrooms studies it appeared that neither was more coercive of student attention or lesson-relevant thinking. However the maths lessons elicited more conscious application of learning processes and more involvement in wider classroom activities, particularly responding to teacher questions. The science lessons involved more interaction with the neighbour and a much greater variety of student mental and physical activity.

The Grade 8 students in this study, when compared with the Grade 10 and 11 students from phase one, were much more straightforward in their reactions and interactions, and were much more compliant. The complex deception strategies and involved interpretations and attributions so prevalent with the more senior students were almost completely absent with the Grade 8 students. The size of difference was an unexpected result and appears a fascinating area for future research.

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THE SATISFACTION OF YOUNG CHILDREN WITH THEIR REPRESENTATIONAL DRAWINGS OF NATURAL PHENOMENA

Dorothy Hayes and David Symington

INTRODUCTION

Asking children to communicate by means of drawing, painting, and modelling is very common at the primary school level. In science activities children are often required to record their observations of natural phenomena by these methods, particularly drawing.

Although psychologists have been researching children's drawings for many years (e.g., Luquet, 1927; Eng, 1954; Freeman, 1980) educational researchers, with the exception of those interested in art education, have made very little contribution to our understanding of this area. It is probably not so surprising, therefore, that much of the research has been focussed on issues of perception, cognition, and child development and that less attention has been paid to some other issues of importance for teaching such as motivation.

From the teacher's point of view an important consideration is whether the children themselves are satisfied with their efforts. Satisfaction is likely to provide motivation for the next similar experience, whereas lack of satisfaction is liable to lead to lack of motivation. Children's satisfaction with their drawings has not been adequately explored in previous research and so was chosen as the focus of this study.

METHODOLOGY

A number of important issues had to be considered when making decisions about the methodology to be employed. The first was the context of the study. It seemed that if the study was to yield data useful to teachers about the children's satisfaction with their drawings these should be produced in a setting as close as possible to that in which children would normally work. Accordingly the drawing activity was carried out in a normal class program, as one activity within a topic which the children were studying. There was a purpose for the drawing as far as the children were concerned, each was to communicate sufficient detail about the shell represented that the other children could identify the shell drawn. The children were able to talk with their peers and the teacher during the activity.

A second issue was how to obtain data on the students' satisfaction with their drawings. It was decided that the most appropriate way was to ask the students themselves. Whilst appreciating the concerns that some may have about the validity of such data we felt that because the drawing activity had been part of the on-going life of the classroom, and since the question was to be asked by a person with whom the children had developed a trusting relationship, namely their class teacher, it seemed reasonable to gather the data in this way. Additional objective data were gathered by videotaping the activity and noting problems children had with the task.

Choosing the Topic

Psychologists involved in studying children's representational drawings of three dimensional objects (e.g. Chen & Cook, 1984) have largely focussed on the problems involved in translating the model seen into a two dimensional set of lines, and show a preference for the use of regular solids as models. In the classroom setting when children are asked to draw a three dimensional object they are usually able to use a range of properties to communicate about the object. Even if they have difficulty representing the three dimensional shape they may be able to effectively convey information about the object by the use of colour. For this study it was decided to use the type of object the children would commonly collect, in this instance they were asked to draw shells.

The Research Questions

The main research question was: 'Do grade 1/2 children experience satisfaction in creating representational drawings of shells for use in a matching activity?

Since one of the factors which could influence the children's satisfaction is their perception of the properties they see as important to communicate, another question posed was: 'What properties do grade 1/2 children see as important to be communicated in representational drawings of shells to be used in a matching activity?'

The Context

The study of shells was part of a larger topic 'The Beach'. The children had become quite involved in the study and brought shells and relevant posters and books to school. Many class and small group activities had arisen from the topic and the children had numerous opportunities to handle and observe a variety of shells.

Several days prior to the drawing task the children were asked to select a shell that they liked. These shells were then mounted on cardboard for ease of handling.

The Data Gathering

(i) The Drawing

The context for the drawing activity was provided by telling the children that the drawing was to be used as part of a matching activity at a later time. They were also told that they could use pencils and paper and could alter their drawing by erasing or by obtaining a new piece of paper if they were not satisfied with their drawing. No time limit was set for the task.

The children did their drawing in the normal classroom. They were allowed to move about freely and to discuss their work with their peers. They were able to seek the teacher's attention or approval if they deemed this necessary. The drawing activity was videotaped without the children being aware that this was being done.

(ii) The Matching Activity

The matching activity took place later in the same day. The actual shells were placed along the chalkboard ledge. Individual children were given a drawing which they were to match to a shell. The teacher made a record of the ease with which the matching was done and the properties of the shell which were used to make the match.

(iii) The Interview

The children were interviewed individually, the interview being recorded on audiotape. The questions were designed to obtain data about the properties of the shell the children thought should be communicated by means of the drawing, problems they encountered in doing the drawing, their satisfaction with their drawing and their enjoyment of the activity.

ANALYSES OF THE DATA

As shown in Table 1 almost all of the children (92%) stated that they had enjoyed drawing their shell. The majority (76%) expressed satisfaction with their drawing, although most had experienced difficulties in one form or another as can be seen in Table 2.

TABLE 1

Data, gathered by interview, which indicate the children's reaction to the drawing activity.

- Number of children in the class - 25.
- Number (percentage) of children who expressed satisfaction with their drawing - 19 (76%).
- Number of children who said that they enjoyed the drawing activity - 23 (92%).

TABLE 2

Data, gathered by observation and interview, which reflect the difficulties that the children experienced in drawing the shell.

1. Observational Data
   - Number (percentage) of children who discarded a drawing and began again on a new piece of paper - 3 (12%)
   - Number (percentage) of children who used an eraser - 23 (92%)
2. Interview Data
   - Number (percentage) of children who expressed concern about their ability to adequately portray the colour of the shell - 10 (40%)
   - Number (percentage) of children who expressed concern about their ability to adequately portray the shape of the shell - 8 (32%)
   - Number (percentage) of children who expressed concern about their ability to adequately portray details of the surface of the shell - 7 (28%).

The data show that 92 per cent of the children used an eraser during the activity, this being assumed to reflect some dissatisfaction with an aspect of their initial drawing. This dissatisfaction was confirmed verbally during the interviews. In many cases the problems appear to have, in the children's eyes, been overcome by the use of the eraser. Three children rejected their first efforts altogether and used a new piece of paper.

The interviews revealed three areas in which children experienced difficulties. One of these was the difficulty some children (40%) had with producing an appropriate colour. As a solution some children were happy to substitute one colour for another, for example, yellow was sometimes substituted for white. Another source of concern was the difficulty of portraying the shape of the shell correctly. Reference to this issue was made by 32 per cent of the children. The third area of concern, as expressed by 28 per cent of the children, was the difficulty of portraying surface details such as bumps, breaks or holes.

It can be noted from the analysis presented in Table 3 that where there was dissatisfaction it was normally only with the representation of one of the properties of the shell.

Table 4 sets out the children's opinions about which properties of the shells should be communicated by the drawings. Almost all (92%) of the children believed that the shape of the shell should be communicated. Colour was mentioned by about half (48%) and surface features by a smaller number (16%).

Table 5 represents an analysis of some of the data obtained when observing the matching activity. It will be noted that in the majority of cases (76%) the shell and drawing were matched on either the first or the second attempt.

Probably the most effective means of seeing possible relationships between the various pieces of data is obtained by considering together all the information gathered about an individual pupil.

TABLE 3

Number of children who expressed concern about their ability to adequately portray the properties of the shell in their drawing.

Number of children who when expressing concern about their ability to portray the properties of the shell made reference to:	
1 property only	14
2 properties	4
3 properties	1

TABLE 4

Data, gathered by interview, which reflect the properties of the shells the children thought it important to communicate.

Number (percentage) of the children who thought that it was important to accurately communicate the:
shape - 23 (92%)
colour - 12 (48%)
surface features - 4 (16%)

TABLE 5

Data, gathered by observation, which indicated the ease with which the drawings were matched to the corresponding shell.

The shell and drawing were:	
matched on the first attempt	14
matched on the second attempt	5
matched on the third attempt	2
not matched in three attempts	4

One instance is provided here.

> Robert (Grade 2) stated, when interviewed, that the most important properties of the shell to be communicated were 'the right shape and the right colour'.
>
> He had some difficulty in drawing the shell. As he said: 'It was hard to draw the curved shape'. However, despite the difficulties, he put a lot of time and effort into his drawing and expressed satisfaction with the result.
>
> Robert's drawing would be classed as showing intellectual rather than visual realism (Barrett & Light, 1976) since he included details of the shape of the end not visible from the position from which he was viewing the shell. He also took great trouble to record the surface markings on the shell and to communicate the colours effectively.
>
> During the matching activity his drawing was matched to the shell without difficulty using the shape, colour and markings.
>
> When interviewed, Robert indicated that he was satisfied with his drawing and that he believed that he had communicated to the other children the properties he considered important.

DISCUSSION

The task required of the children - to produce a representational drawing of an irregular solid - was apparently not an easy one. Probably the most important finding of the study, as far as primary teachers are concerned, is the fact that almost all of the children enjoyed this activity, that the majority obtained satisfaction from it, and that in most cases the children could match the drawings to the corresponding shells.

An important question to attempt to answer is: What was the source of their satisfaction? Clearly most had some difficulty in producing their drawing. However, for the majority of these, the difficulty was only with portraying one property of the shell. When it came to the matching activity most found that their communication was adequate for the purpose. It would appear that in the classroom where there are a number of properties about which the children can communicate, difficulty with one of these need not make the child's communication ineffective. For example, some of the children appeared to be able to compensate for an inability to convey the three dimensional shape of the shell by paying adequate attention to the other properties such as colour and surface markings.

There is an obvious need for further research drawing upon other pupils and topics to see whether the interpretation made of these data is sound.

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AN INTERPRETATION OF RESEARCH IN 'CONCEPTUAL UNDERSTANDING' WITHIN A SOURCES-OF-KNOWLEDGE FRAMEWORK

Leo West and Leon Pines

1. INTRODUCTION : LEARNING FROM A CONSTRUCTIVIST PERSPECTIVE

It is well known that there is now a new field of research in science education called 'in-depth investigations of students' conceptual understandings'. Much of this work has concentrated on 'misconceptions' or 'alternative conceptions/alternative frameworks', but this is still part of what we call conceptual understanding. 'Mis-' applies only when the student's private conceptions are compared with some publicly accepted meaning.

Most of the research that we refer to here is conceived within a constructivist view of learning. Among constructivists there is an important distinction between private understanding and public knowledge. Being able, for example, to state some piece of public knowledge like 'Bob Hawke is Prime Minister of Australia' may represent a change in behaviour in some student following instruction, but it does not count as learning for the constructivists. Learning involves a learner in constructing his/her own understanding of some part of the public knowledge. Learning is making one's own sense of public knowledge.

What else characterises constructivist researchers? They are not interested in atomistic learning, that is, in the learning of some small component of public knowledge. Their interest is in the learning of large bodies of structured public knowledge (such as Newtonian physics, the kinetic molecular theory of gases, and the classification and origin of rocks). There does not seem to be a general term for this, but we think that when people use terms like 'conceptualisations', 'frameworks', 'conceptual understanding', they are referring to situations where students are attempting to internalise, to make their own sense of, relatively large bodies of organised public knowledge. It is this type of learning that is the interest of this paper.

Another important shared assumption among the researchers is that the learner's prior knowledge is important in constructing one's own understandings; that the interaction between new knowledge and existing (personal) knowledge is a most

important process in learning. Sometimes prior knowledge can be a bridge to new learning; sometimes a barrier. The major thrust of this paper is to explore this process and use it to interpret the research findings.

2. LEARNERS AS ACTIVE SENSE MAKERS

Along with other constructivists, we see learners as mentally active, as struggling to make sense of their world. This is well demonstrated in Nussbaum's research on elementary school children's conception of the earth as a cosmic body (Nussbaum, 1979); see Figure 1.

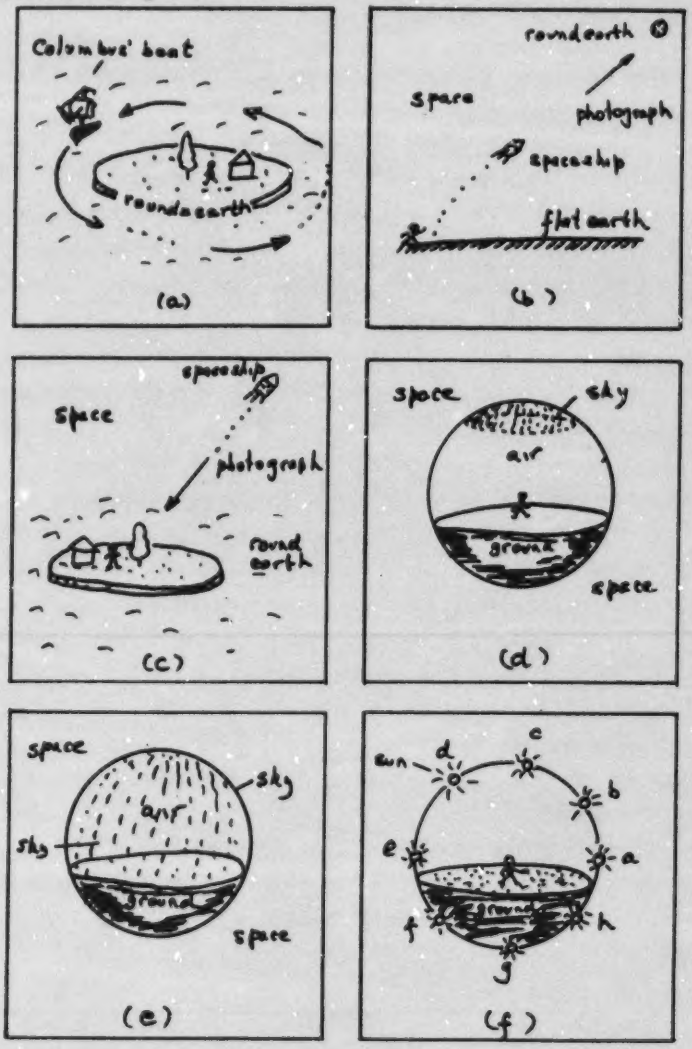

FIGURE 1 Some children's views of the earth as a cosmic body (Reproduced from Nussbaum, 1979)

It is easy to smile at Figure 1(a). What a strange idea. Yet it represents a creative attempt by a child to make sense of several pieces of public knowledge: the earth is round; Columbus sailed around the world; to our eyes the earth is flat, except for a few hills and valleys. In 1(c), the child has made sense of spaceship photographs showing a round (but 2 dimensional) earth. Figure 1(d) is a creative piece of sense making, as is Figure 1(f) which is used to account for molten rocks below the earth's surface (heated by the sun at night time). We use these data to make two points. Firstly, children's misconceptions arose from attempts to make sense of the various inputs of public knowledge. Secondly, we should marvel at the creative ability of these sense making attempts and value and reward such efforts. Science education should encourage not discourage such efforts; the sense making process is at the centre of real learning.

3. A SOURCES-OF-KNOWLEDGE VIEW OF SCIENCE LEARNING

We find it useful (following Vygotsky, 1962) to identify two sources of knowledge in the individual. There is the knowledge that a child acquires from interaction with the environment: this is intuitive knowledge, 'gut' knowledge, naive knowledge. It is influenced by language, culture, and other individuals. Such knowledge is a person's own sense-making of the environment observed, tempered, and manipulated by interaction with television, parents, peers, and others. Its primary characteristic is that it constitutes the person's reality. Another characteristic is that this type of knowledge is acquired in a rather haphazard fashion, over considerable time, and without any particular direction. We do not set out to learn the nature of the earth as a cosmic body, for example. We know that the earth is flat to our eye, yet round from photographs from space. We know about satellites, the Shuttle, and a whole gamit of other things. At any time in our lives we have a particular conception of the world which we believe, think of as reality, 'know' is shared by our peers.

The other source of knowledge is formal instruction, disciplined knowledge, school knowledge. It is someone else's interpretation of the world; someone else's reality. Its primary characteristic is authority. It is 'correct'; it is what the book says; what the teacher says. It is approved by other people who are usually older and more highly regarded than the student. Our learning of this knowledge is goal directed, and we are usually expected to learn it in a certain time period, and to demonstrate, most often through tests, what we have learnt.

As we said at the beginning, learning, to the constructivist, is the process in which learners make their own sense of inputs. Learning involves the

interaction between the learner's present understanding of the world and the knowledge input. Of course, much of what passes for learning is quite different from this. One can read in the burgeoning alternative frameworks literature (for example, Driver & Erickson, 1983) that the learning of isolated pieces of knowledge to which the learner has no commitment is commonplace. But, we are concerned here with genuine attempts to make sense of school knowledge.

Let us return to our two sources of knowledge and introduce a metaphor that we find useful. Our view of genuine conceptual learning is the integration of knowledge from these two sources. We find a vine metaphor useful in understanding this intergration. We imagine two vines representing these different sources of knowledge, one originating from the learner's intuitive knowledge of the world (which we call the upward growing vine to emphasise that it is part in the growth of the learner), the other originating from formal instruction (which we call the downward growing vine to emphasise its imposition on the learner from above). Genuine conceptual learning involves the intertwining of these two vines. The vine metaphor emphasises that once integration occurs, the sources of particular parts of the intertwined vines are impossible to identify - indeed, at that point, the question of source may be irrelevant. At the point of integration, however, the sources of knowledge are most important.

One can imagine different situations that arise, depending on the nature of our two vines. We identify four extremes,

a) Conflict situation

Both vines are well established but they are in conflict. In this situation the learner's reality, the ideas believed and to which he/she is committed are in conflict with the principles being presented, which carry with them the authority of the discipline and the endorsement of the school. Mature learning in this case involves transferring one's commitments from one set of ideas to another. It demands the questioning of one's reality; the abandonment of ideas that have been established over a long period - ideas that one knows are still held by members of one's subculture.

b) Congruent situation

Both vines are well established but not in conflict. In this situation the student's reality can be integrated with the school knowledge without special problems. There is no reality shock, no need to abandon old commitments. There is simply an extension and an integration of one's reality into a bigger perspective. When the school knowledge is presented, it merely reinforces existing ideas, integrating them into a larger whole, extending one's understanding of the world.

c) Symbolic knowledge situation

This is the situation where there is hardly any upward (intuitive knowledge) vine to interact with the downward (school knowledge) vine. An example is the learning of freshman, organic chemistry. There is little in the learner's intuitive knowledge that is relevant to the learning of, for example, the substitution reactions of benzene and its derivatives. For the student, this is an attempt to acquire pure symbolic knowledge. Even laboratory classes do not provide many elements of reality. It is doubtful that many freshmen chemistry students have seen, felt or smelt benzene yet they spend considerable time studying its chemistry.

d) Uninstructed situation

This is the case where there is little or no formal school knowledge vine; where all of the learner's knowledge is based on intuitive learning.

Conceptual Development

The above idealized typology can be used to address the issue of school science learning. Acquiring relatively large bodies of complex, inter-related knowledge in school settings probably always begins as a symbolic knowledge situation. Given the authority and the demands of schooling, novices are usually forced to begin by ignoring their own reality. So, if learners want to make a genuine effort to make sense of this knowledge (as opposed to rote learning numerous isolated bits), they will need to concentrate on integrating and differentiating the symbolic knowledge. Instructional strategies and devices like concept maps (Novak, 1981; Fensham, Garrard, & West, 1981) are designed to encourage and reinforce integration and differentiation of the various parts of school knowledge being presented to the learner. The concepts of a concept map are drawn from new learning (the downward vine), and not from the student's prior knowledge.

The functional image elicited by the vine metaphor of these procedures is that of increasing the intertwining and consolidation of the various branches in the downward growing vine, here and there allowing a single runner to push ahead, maybe intertwining with a runner from a different branch, or forming the beginning of a new expanding growth. The general image is of gradual expansion and increasing intertwining. It might be useful to dub this process 'conceptual development'.

Conceptual Resolution

At the extremes of this developing vine there will occur interactions with the upward growing vine of the learner's real world knowledge. Sometimes these will be conflict situations; at other times congruent situations. The former does not constitute a major reality shock of the kind that might confront a flat earth believer

who sees a round world from space, but rather a minor conflict which on its own does not have to be resolved. For example, the learner can bypass the conflict by deciding to have two meanings for a word like 'work' - one for school physics, and one for the world of experience. Or, of course, the learner can try to create a relationship between these two meanings, or try to see the physicist's reason for retaining the word 'work' but redefining its meaning. For many learners this would both resolve the conflict and open up avenues for further integration of the two vines. Instructors who prefer the latter, find techniques such as the IAI attractive as instructional tools, as Gilbert and Osborne (1980) workshops for teachers have demonstrated. It might be useful to dub this process 'conceptual resolution'.

We do not wish to imply an under-valuing of this process. For children such conflicts might be a major importance. Nor are we sure whether conceptual resolution should be attempted early or only after considerable conceptual development has been achieved. There is one example in Happ's research (Happs, 1984) where he began the children on conceptual resolution early. They were happy to play the school science game, but did not seem to be ready to accept the transition.

For conceptual resolution involving a conflict situation we consider Osborne and Gilbert's interview about instances technique (IAI), and Kelly repertory grids (Kelly, 1955; Pope & Keen, 1981), used as instructional tools to be potentially effective. For conceptual resolution involving a congruent situation, the use of advance organizers or Venn diagrams (Gunstone 1980) seem to be appropriate.

Conceptual Exchange

What happens when the conflict situation is major? When the conflict is not just between one branch of one vine and one branch of the other, but between whole vines? Here we have substantial reality clash. The classic examples are of an Aristotelian-like view (which is a common intuitive framework) challenged by Newtonian physics, and the Newtonian view, when eventually accepted, challenged again by Einsteinian physics. The former has been extensively researched (Champagne, Klopfer, & Gunstone, 1984) and the latter has been the content area of a series of investigations by Posner, Strike, Hewson, and others (Posner, Strike, Hewson, & Gertzog, 1982). The resolution of such conflicts is a painful process which is difficult to achieve (Champagne, Gunstone, & Klopfer, 1984).

The term conceptual exchange has been used to describe this process, and seems to us to be an appropriate descriptor. The nature of conceptual exchange has been

explored at a theoretical level by Strike and Posner (1984) and Hewson (1983) although, as West and Pines (1983) pointed out, this theoretial description ignores important non-rational components of conceptual exchange. A number of researchers have developed teaching strategies to assist conceptual exchange. The strategies usually involve three phases - an awareness phase, a disequilibrium phase, and a reformulating phase.

The awareness phase for Erickson (1980) involves 'experiential and clarification manoevres' in which the teacher provides a range of experiential activities followed by class discussion to elicit and emphasize the existence and nature of competing viewpoints in the class. Nussbaum and Novick (1981) proposed and tested the effectiveness of a similar technique. Champagne, Klopfer, and Gunstone (1984) proposed the use of a set of physics problems and student teacher dialogue with the same aim. Posner et al (1982) suggested that this phase involves the student actively seeking to make sense of new learning within his/her existing framework and finding that unsatisfactory. They suggest that teachers should spend a substantial portion of their time diagnosing student thinking errors and identifying defensive moves that students use to resist conceptual change.

The disequilibrium phase for Erickson and Posner et al. involves the use of anomalies introduced by the teacher which challenge existing frameworks. Nussbaum and Novick called the anomalies they used 'discrepant events'. They involved the students in articulating the lack of consistency between the events and their particular framework. Posner et al. state, and others imply, that during this phase the teacher needs to adopt an adversary role in the sense of a Socratic tutor.

The reformation phase involves, for Champagne et al., Erickson, and Nussbaum and Novick, the presentation of the experts' conceptualization with emphasis on the resolution of anomalies.

The application of such a set of strategies appears to be less successful than anticipated. It is possible that before conceptual exchange can be achieved, a considerable amount of conceptual development covering the new material may be necessary. Strike and Posner imply that conceptual exchange strategies will be successful only if substantial understanding of conceptual knowledge has been achieved. This is supported by the research of Champagne, Gunstone, and Klopfer (1984) in which conceptual exchange strategies worked well with University graduates while the same strategies were unsuccessful with bright middle school students.

4. IMPLICATIONS

Let us recapitulate our personal understanding of the research into conceptual understanding that has become such an important area of science education research. This research is concerned with conceptual understanding of the coherent bodies of organized knowledge that form a significant part of school and college science curricula. The researchers share a constructivist view with respect to such learning. They consider that genuine conceptual learning occurs when learners make their own sense of such knowledge.

There is something of a contradiction here. The curricula of schools and colleges are other people's knowledge, imposed (with the power of authority) on the student. Not surprisingly some students do not bother to make personal sense of this knowledge but merely play the school 'game' of rote learning and reproducing the curriculum knowledge. But what of those who genuinely attempt to understand school knowledge? How does this expanding area of research in science education help?

The misconceptions research has potential to hinder rather than help. The research results might be used to ridicule both students and teachers. It could easily devalue the efforts of science teachers to share their meanings with their students, and the efforts of their students to make sense of this science knowledge. It would be counter productive if the misconceptions research motivated teachers to set out to 'remove' each new misconception that was identified in the literature, or to begin extensive testing of their own students for such misconceptions. Such activities would indeed act to devalue students' previous learning efforts and to hold them up for ridicule.

Rather than take such a narrow perspective, we prefer to examine what the research tells us about students' conceptual science learning in general and not to concentrate specifically on misconception. Conceptual science learning is not a single entity. We have found it useful to identify three separate learning processes - conceptual development, conceptual resolution, and conceptual exchange - and to associate particular research findings to one or other of these processes. Of course, the learning of a particular science topic will rarely involve just one of these processes. Their separation is made to aid the generalisation of research findings.

In the context of schools and science curricula as they operate now, some meaningful science learning will be what we have called conceptual development. It involves the student in integrating and differentiating a set of propositions, examples,

algorithms, and so on, most of which are symbolic knowledge having little, if any, reference in the student's reality. For this process, strategies like student constructed concept maps are valuable aids to meaningful conceptual development. While we do not consider that conceptual development is sufficient on its own, we do see it as an important component in meaningful science learning.

In addition to this developing conceptual vine, there will be the places where it does touch reality; places where conceptual resolution will be important. Here, instructional strategies like interviewer-about-instances, repertory grids will be valuable in resolving conflicts, while strategies like Venn diagrams and advance organizers will be useful in building bridges between the student's world and school science.

Occasionally science students face the formidable task of conceptual exchange. When this occurs, conceptual exchange strategies like those described earlier will be invaluable.

For us, this particular typology of conceptual understanding seems to be valuable. If it turns out not to be useful to others, then we urge them to explore other typologies. What seems certain is that different types of learning are being explored by science education researchers in the current movement. To see the research applied to some single construct 'science learning' is, we believe, mistaken.

The summary above applies to science curricula and schools as they are currently oriented. But the vine metaphor we used has important implications for an alternative conception of science education. Should science education be concerned with imposing the downward growing vine? A case can be made for school science to be concerned with the development of the upward growing vine; concerned with extending the experiences of children and of their sense-making within an intuitive knowledge framework. This implies giving value to children's sense-making attempts even though their conceptualisations do not match scientists' conceptualisations of the same events. It implies non-goal directed learning (in the content sense). There is a powerful argument that if the true goals of science education are to enable our future citizens to understand the scientific world in which they will live and to strive to make sense of that world, then science education will need to concentrate many more of its efforts in the development of our upward growing vine. To instruct students in other people's knowledge, and to test them on the extent to which they have internalised that knowledge, is not likely to develop in them a propensity to try to make their own sense of the scientific world in which they will spend their future lives.

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LEARNING STRATEGIES OF ONE STUDENT ON A RANGE OF CLASSROOM TASKS

Gloria Dall'Alba and Jeff Northfield

INTRODUCTION

Much early research on differences in the outcome of learning has focussed on a quantitative description, that is, on how much is learned. Marton (1975) criticises this preoccupation with the quantitative outcome of learning at the expense of the quality of learning that has taken place. He stresses the need to examine what is learned, rather than how much is learned. Studies that have examined the question of the quality of learning (Goldman, 1972; Marton, 1975; Martin & Saljo, 1976a; Pask, 1976a, 1976b; Svensson, 1977; Brumby, 1979; Baird, 1980) provide evidence of qualitative differences in the learning outcomes. They give rise to an important question for research into learning: How can qualitative differences in learning be ascertained?

COGNITIVE STRATEGIES RESEARCH

Baird and White (1982a) provide evidence of qualitative differences in learning in terms of application of cognitive strategies. A major implication is the promotion of self-control of learning by 'increasing learner awareness of the nature and process of learning, and by training learners in procedures for enhancing self-evaluation and decision-making' (Baird & White, 1982b, p.227).

At present students do not generally receive instruction on the learning process. It is simply expected that they will gain an understanding of the learning process as they engage in it. When so little is known about this complex process, it seems unrealistic to expect that in some undirected and unexplained way, students will imbibe principles of effective learning. Research into understanding the learning process and its communication to the learner is urgently needed. This paper introduces a study to assess qualitative differences in learning in terms of application of cognitive strategies. It is part of a larger project to explore the effects on learning strategies of three learner attributes - prior knowledge, conceptualisation of the task, and attitude to the task.

RESEARCH DESIGN

Since the study is concerned with the application of cognitive strategies by individual learners a case study approach will be adopted. To promote application of a range of strategies, tasks that are distinctly different in nature will be used. Secondary science students will engage in tasks of different types, such as reading an illustrated passage of science text, carrying out an experiment, making notes on a passage, and undertaking a problem-solving activity.

Two approaches to identifying learning strategies may be taken. Each answers a different question. On the one hand, tasks may induce specific strategies. This approach would be directed toward identifying those strategies that the learner CAN apply. Alternatively, tasks may simply provide opportunities for the application of strategies. In line with the latter approach, this study is concerned with those cognitive learning strategies that the learner DOES apply in a given context.

While there will be variation in the type of tasks and hence, in the learning context, the learner is the feature that will be held constant. The cognitive strategies applied by each learner will be monitored for each task.

Identifying Cognitive Strategies

Studies concerned with identifying approach to learning or level of processing (Marton & Saljo, 1976a, 1976b; Svensson, 1977) and learning strategies (Baird, 1980; Marland & Edwards, 1982; Edwards & Marland, 1983) have most commonly relied upon self-report data obtained in clinical interviews. While this method has proved to be extremely time-consuming, it has yielded insights which would not be expected from the use of other methods.

The focus in the present study will be on cognitive learning strategies at a specific and detailed level. Baird's (1984) scheme will be used to identify strategies. (See Box 1 for a summary of the scheme and Box 2 for the expanded form of strategy 1.)

The clinical interview, in association with observation, appears to be the most appropriate technique for identifying strategies. It will provide opportunities for undirected responses by the learners and for further probing and clarification by the interviewer. Such opportunities are likely to enhance and to be necessary for identification of cognitive strategies.

BOX 1

Summary of Baird's (1984) Tentative Classification Scheme
for Some Evaluation Strategies Involved in Learning Written Information

Strategy Type and Number	Nature of Strategy
Group A	Information reception, processing to establish meaningfulness, and subsequent processing approach.
1	RECEIVE INFORMATION
2	ESTABLISH MEANINGFULNESS
3	DEFINE TASK AND ESTABLISH PROCESSING REQUIRED
4	CONSIDER ADVANTAGES AND DISADVANTAGES OF ALTERNATIVE APPROACHES (COST-BENEFIT EVALUATION)
Group B	Decisions about ongoing information processing: choice and mode of application of appropriate rules, intellectual skills, and schemata; modifications to existing cognitive structure; extent of processing.
5	MONITOR PROCESSING
6	ELABORATE KNOWLEDGE AND UNDERSTANDING ('REFLECTIVE THINKING')
7	COMPLETE PROCESSING
Group C	Decisions about outcome
8	EVALUATE OUTCOME
9	EVALUATE REVISION OF COGNITIVE STRUCTURE AND FUNCTION; ESTABLISH CONTEXT FOR FUTURE LEARNING

In audio-taped clinical interviews, the learners will be encouraged to 'think aloud' as they perform tasks of different types. They will be questioned at intervals on their thoughts and procedures. Following each task, they will select those descriptors applicable to themselves from a checklist of statements indicative of cognitive learning strategies (the checklist will be discussed and presented later: see Box 4). Each statement will be typed on a separate card. Examples of such strategy-related statements are:

I thought about how I would use the equipment.

I looked for the important ideas.

In line with variations in the nature of the tasks, the checklist will be modified for each task. So, the former example of a checklist statement would be suitable for the experiment or problem-solving activity but would be omitted for making notes on a passage. The latter statement would be appropriate to all three of these tasks.

BOX 2

Strategy 1 from Baird's (1984) Tentative Classification Scheme
for Some Evaluation Strategies Involved in Learning Written Information

Strategy Type and Number	Nature of Strategy	Examples of questions which would direct strategy application
Group A. Evaluation Strategies associated with decisions about information reception, processing to establish meaningfulness, and subsequent processing approach.		
1. Receive information		
1.1 Establish general topic, activate appropriate content-related schemata.		What is this all about? What does this involve? What does this relate to?
1.2 Evaluate: general nature and extent of knowledge and understanding for these schemata;		How much do I know about ... ?
affective features of these schemata (previous history of success or failure, level of interest, attitudes, beliefs).		What are my feelings about ... ? E.g., How important, interesting ... is it ?

Each statement that is selected from the checklist will be rated on a three-point scale in terms of its usefulness in accomplishing the task (not useful/useful/very useful) and the frequency with which it occurred (very few/sometimes/often). The learners will then be asked additional questions aimed at providing evidence for strategy application. Appropriate measures of learning outcomes will be obtained for each task.

To date, the data collection has consisted of establishing the suitability of the tasks for enhancing the identification of learning strategies. Six secondary students have been involved in a pilot study. In this paper the profile of cognitive learning strategies will be presented for one of these students, Gary.

PROFILE OF COGNITIVE LEARNING STRATEGIES

Data have been gathered on Gary's application of strategies for four different tasks. In this section, his application of strategies will be discussed, a) in an expanded form for one task, a problem-solving activity, and b) across the four different tasks.

a) Learning strategies of one student on a problem-solving activity. The activity was introduced to Gary in an audio-taped interview (see Box 3).

BOX 3

Introduction and Instructions for Problem-Solving Activity

I have an activity that I'd like you to do.
As soon as you begin I'd like you to tell me what you're thinking about as you do it.
You might think about how you'll do it, whether it seems interesting, boring, hard, too easy, or about things that have nothing to do with what you're doing.
When you've finished I'll ask you some questions about what you did.

Instructions:

There are lots of different kinds of sticky tape sold in the shops. Each manufacturer claims that their tape is best.
You have been given three different kinds of tape labelled X, Y, Z.
This is what you have to find out:
WHICH KIND OF TAPE STICKS MOST STRONGLY TO THE BOARD?
You can use any of the things in the box.
Choose whatever you need to answer the question.
Make a clear record of your results so that another person can understand what you have found out.

(Adapted from APU at 15, 1983)

I've typed the instructions on a card in case you want to remind yourself sometime about what you have to do.

As Gary carried out the activity the first author/interviewer recorded observations of how the task was performed and encouraged him to 'think aloud'. When Gary sought assistance, the instructions were repeated or clarified, with care taken to avoid directing strategy application.

On completion of the task, Gary selected descriptors applicable to himself from a checklist of statements indicative of learning strategies. A checklist blueprint is presented in Box 4. Each statement selected was discussed in turn, in an attempt to obtain evidence to support its occurrence.

The data used in the identification of strategies consisted of transcripts of the 'think aloud' data, written observations made by the interviewer, the selection and discussion of checklist statements, and the student's written record of results. Table 1 shows the strategies that were applied in the problem-solving task (using the scheme outlined in Box 1) and the associated frequencies.

BOX 4

General Checklist for Identifying Strategies

Topic
- I thought about what it* was all about.
- I thought about other things I know about this topic.
- It made me think about things I've seen and done.
- I thought about whether I was interested in this topic

Detail
- I realised how I was doing the task (for example, carefully or in a casual way).
- I looked for the important points.
- I thought about how the important points fitted together.
- I thought about whether I understood what I was doing.
- If I didn't understand I did something about it.
- I remembered other things that helped me to understand.
- I thought about whether the information agreed with my ideas.
- I had some questions about the task that I did not ask.

Task
- I thought about whether I understood what I was asked to do.
- I thought about whether I was given enough information for the task.
- I thought about how I could use the equipment.
- I planned what I would have to do.

Approach
- I thought about how long it would take.
- I thought about how hard it would be.
- I thought about other ways of doing the task.
- I thought about why I was doing the task
- I thought about how I would use the result.
- I thought about whether I would be able to finish the task.

Change in Knowledge
- I thought about how the information/result compared with what I know.
- I thought about how the information/result compared with what I expected.
- Some of my ideas were changed.
- I thought about whether the information/result made sense to me.
- I thought about whether the information/result seemed correct.

Increase Understanding
- I thought about what might happen if something were changed. (For example, What if ... ?; What about ... ?)

Progress
- I thought about how I was going with the task.
- I thought about what I should do next.
- I thought about whether I was doing the task in the best way.

Completion
- I thought about whether I had done enough to stop.
- When I had finished I thought about whether I understood it all.
- I thought about what I would need to do to understand it all.
- I thought about whether I had finished what I was asked to do.

Future Use of the Knowledge
- I thought about how I could make sure I remembered the new information.
- I thought about how I could make use of what I'd learned in future.

*Underlined words and phrases in the text are general terms that are expressed more specifically in the checklists for each task.

TABLE I

Frequency of Strategies for One Student on Four Tasks

Strategy Number	Strategy Type	Task			
		Reading*	Problem-Solving	Making Notes	Experiment
1	Relating	39	2	19	6
2	Meaning	8	7	4	14
3	Define task	-	2	8	11
4	Evaluate approach	4	7	3	7
5	Monitor processing	4	5	6	10
6	Elaborate	1	-	-	-
7	Complete processing	-	2	1	2
8	Evaluate outcome	-	1	3	2
9	Evaluate revised cognitive structure	-	1	-	2

*The reading task was the only task for which the checklist was not used in identifying the strategies. There is some evidence that use of the checklist enhanced the identification of Strategies 7, 8, and 9.

In comparison with previous trials of this task with other students Gary showed a lower incidence of Strategies 4 (evaluate approach) and 5 (monitor processing). He appeared to formulate a conception of the task, conceive of a plan and carry it out immediately. He did not test alternative methods (one indication of Strategies 4 and 5) but reported being satisfied that he had answered the question. His initial investigation was directed to answering the question he was given, viz., which kind of tape sticks most strongly to the board. However, he then attempted to provide further evidence by demonstrating which was the strongest tape. In applying Strategy 3, defining the task, he seemed to confuse sticking strongly to the board with strength of the tape. The written record of his results includes a discussion of how strongly each tape adhered to the board and of strength of the tapes.

Gary's application of Strategy 3 is worthy of note for three reasons. Firstly, it provides an interesting example of application of this strategy. Secondly, it illustrates how strategies may be applied in a way that is not in accordance with the given task. Finally, this example indicates that application of a strategy is included in the frequency count whether or not it accords with the task.

Some other interesting observations were made during the problem-solving activity. Throughout the investigation Gary relied solely on his own observation, providing totally subjective judgements. There was no evidence that he had considered any form of measurement to be useful in answering the question. He did not control for length of tape.

b) Learning strategies of one student on four different tasks. Table I shows the strategy number, type and associated frequencies for Gary on four different tasks. Each strategy will be considered across the four tasks and in relation to other strategies for the same task. Comparisons will also be made with other students involved in the pilot study. No comparisons are possible for the experiment since only Gary has performed this task at this stage.

Strategy 1 Receive information: Relate to prior knowledge or experience and associated affective responses.

The frequency of occurrence of Strategy 1 was very high for the reading task and when Gary was reading prior to making notes. It was higher than that of any other strategy for all students on all tasks. Why did this high frequency occur? Was it a characteristic of the task or, perhaps, of this student? When more data are obtained in the larger study it is hoped that they will suggest answers to some of these questions.

While engaged in the experiment and problem-solving, Gary appeared to concentrate on the task itself, with fewer instances of relating to prior experience. The other two students who performed the problem-solving activity also showed a low frequency of Strategy 1, especially when compared with their application of those strategies which focussed on the task itself.

Strategy 2 Establish meaningfulness: Identify important ideas and attempt to increase their meaningfulness.

On all tasks Gary tried to understand what he was doing - he searched for meaning. For example, when making notes on a passage he acknowledged thinking about whether the information made sense and went on to explain by saying, 'You've gotta make sense of it before you know it' and 'It's gotta make sense to you'. The frequency of Strategy 2 was high for the experiment since he attempted to interpret the results of each of the measurements as he recorded them, that is, on 11 occasions throughout the experiment.

The frequency of this strategy appeared low for the task that required making notes. On this task few separate instances of strategies concerned with establishing meaningfulness were recorded. However, Gary reported searching for meaning all the time while making notes, as did the second student who performed this task. This occurrence highlighted a difficulty in the data collection which will be discussed in a later section.

Strategy 3 Define task and establish processing: Decide what are the task requirements including processing, time, difficulty.

No instances of this strategy were recorded for Gary on the reading task, perhaps due to familiarity with this type of task: (the frequency was also generally low for other students on the reading task). In problem-solving Gary quickly settled on a method and immediately proceeded with it. This approach may be contrasted with that of two other students. The first spent a considerable time clarifying the task, while the second had difficulty grasping the purpose of the activity and made several attempts to define other tasks.

When making notes the frequency of Strategy 3 was inflated by Gary's concern with the time required to complete the task. (He wanted to go to a football game.) The frequency on this task was similar for another student who displayed a desire to do the task well. The higher frequency for the experiment was due to seeking clarification about the requirements of the task, for example, the number of measurements required.

Strategy 4 Evaluate approach: Decide how to carry out the task and assess reasons for performing it.

Frequency of Strategy 4 was higher for problem-solving and the experiment than for the remaining tasks. The higher frequencies may be due to the possibility of proceeding in several ways, with a need for decisions about the approach taken. Two other students also showed a higher frequency than other strategies while problem-solving.

Strategy 5 Monitor processing: Interpret and evaluate understanding of new information and evaluate methods of proceeding.

On all tasks Gary consistently showed a tendency to monitor processing. Lower frequencies of Strategy 5 on the reading and problem-solving tasks reflect the more directed way in which these two tasks were approached, showing less concern with the way in which these tasks were progressing.

Strategy 6 Elaborate new information in terms of content or new associations.

According to the measuring procedures used Gary (and the other students) did not show a tendency to elaborate on the new information.

Strategy 7[1] Complete processing: Evaluate adequacy of outcome in terms of task requirements.

Following development of the checklist, the consistent identification of Strategy 7 shows that Gary checked whether he had completed the task. The low frequencies are to be expected since this strategy occurs only at the end of the task. Application of this strategy was more frequent for Gary than for the other students.

Strategy 8 Evaluate outcome: Evaluate understanding of outcome and personal cost.

When the checklist was used, the consistent occurrence of Strategy 8 shows Gary's tendency to evaluate the outcome of his efforts. The low frequencies are due to application of the strategy at the end of the task only (as in problem-solving) or at the end of each sub-task (as in making notes and the experiment).

Strategy 9 Evaluate revised cognitive structure and consider future learning.

The absence of Strategy 9 on the reading task and when making notes is not surprising since the tasks were performed in isolation and with no apparent relation to future learning. It is surprising that the strategy was applied at all. Application of this strategy in the experiment and problem-solving activity shows that Gary has some tendency to reflect on the future use of new knowledge.

DIFFICULTIES ENCOUNTERED

(i) It is not possible to gain direct access to the mind of another, so identification of strategies must be inferential to some extent. It can be based on several sources of evidence, however, allowing some degree of triangulation.

(ii) Since strategy identification is based upon several sources of evidence, one difficulty that arises is in determining which judgement or source is most valid or reliable when conflicting evidence emerges.

(iii) There may be no confirming evidence from a second source for some strategies. However, students usually can give examples to illustrate where such strategies have been applied.

The possibility exists that at least some strategies without a second source of evidence may have been applied retrospectively, for example, when the interviewer asked a question following the task.

During the data analysis strategies with and without additional supporting evidence will be separated. Greater emphasis will be placed on those which can be supported by additional sources.

(iv) The presence of the interviewer may affect the application or self-reporting of strategies. The use of the checklist has been found to alleviate difficulties associated with the self-reporting of strategies that have been applied.

(v) Intervention in the form of 'think aloud' or questioning by the interviewer may affect application of strategies, that is, the measuring instruments may alter what is being measured.

(vi) The instructions that are given are likely to influence the strategies that are applied. The same introduction to each task will be used for all students. A specific task or question will be presented so that the task may be maintained as a constant factor.

(vii) Application and/or identification of learning strategies in later tasks may be affected by the earlier tasks and interviews. The tasks will be administered to all students in the same order to minimise differences in effects due to prior tasks; hence the effects could be expected to be comparable for all students. Data analysis for each task must incorporate the possibility of such effects.

(viii) Frequency of strategy application is a useful measure for comparison across students and tasks. However, frequency counts are not straightforward. Few separate instances of application of a strategy may be reported but the strategy may be an on-going one. For example, a low frequency of Strategy 2 (establish meaningfulness) was recorded for Gary when making notes on a passage, although he reported that he had looked for main points throughout the exercise. Rating of checklist statements on frequency with which they occurred provides some additional data on this issue. Recording presence or absence may prove more appropriate than frequency counts for some strategies.

(ix) The study may be challenged on the grounds that it is atypical of 'normal' classroom or learning conditions. The study simply attempts to provide insight into qualitative differences in learning. Its relation to more usual conditions would seem to be a logical extension for future research. Learning behaviours in the classroom may be different from those that are reported in this study, leading to exploration of why this is the case.

THE PILOT STUDY IN CONTEXT

In this paper a profile of cognitive learning strategies has been presented for one student on four learning tasks. The beginnings of characteristic patterns of strategy application across the tasks have been demonstrated and contrasted with those of other students. The data provides a glimpse of trends that can be expected to emerge from the larger study of the application of cognitive learning strategies.

REFERENCE NOTES

Note 1. In the reading task the checklist was not used since it had not yet been developed. Use of the checklist for the tasks that followed seemed to greatly enhance the identification of Strategies 7, 8, and 9. In the reading task these strategies were not identified for any students.

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Research in Science Education, 1984, 14, 69-77

DISPLACEMENT OF WATER: WEIGHT OR VOLUME? AN EXAMINATION OF TWO CONFLICT BASED TEACHING STRATEGIES

Chris Dawson and Jack Rowell

In earlier work (Rowell & Dawson, 1979, 1981, 1983) we have attempted to develop the Piagetian notion of equilibration as a basis for teaching strategies designed to change students' ideas about various scientific problems.

Like others we have utilised methodologies which have sought to encourage students to confront their beliefs with reality and with other beliefs, and to evaluate the relationships between these. Both confirmation and conflict have resulted from these evaluations, but it has generally been anticipated that resolution of conflict would be of particular importance in stimulating concept development. Like others we have met with some, but always limited, success with these methods.

Approaches to conflict based teaching have tended to parallel the falsificationist's view of progress in science. A scientific theory is falsified, and hence rejected, if it does not fit the empirical evidence. However this view of science has its critics and Lakatos (1974, p. 119) suggests that '... there is no falsification before the emergence of a better theory'. Rowell (1983, p. 70) has also argued that, for the individual, equilibration operates '... to gain maximum power over the environment whilst conserving as much as possible of what is already known about it'.

Here are suggestions then that it may not be easy to change a student's ideas about the world simply by bringing them into continuing conflict with other views or with reality; and this is in fact what has been observed in many studies. Instead there seem to be sound theoretical reasons for attempting to provide students with a more powerful explanatory idea than they already have <u>before</u> they are asked to compare the two. Within such a strategy, conflict would, instead of being a continual process, be delayed until the intended replacement is well understood.

In this study, two short conflict based teaching methods were developed to attempt to help students understand that the volume of an immersed object, rather than its weight, is the sole factor which determines the water level rise caused by its immersion. One method utilised an orthodox conflict (OC) approach, the other a framework replacement (FR) strategy.

The content of the teaching sequence was chosen for two reasons. Firstly, in previous studies we have found that a considerable proportion of Year 9 students gave weight based arguments in explanation of various problem situations involving water displacement, and it was expected that the proportion would be higher still for Year 8 students, the target group of this study.

Secondly, it was believed that in this content area we have a clear example of two 'alternative frameworks' (Driver & Easley, 1978). An 'alternative framework' is characterised by a degree of homogeneity in the way in which a range of problem situations is interpreted. However the term is used loosely and a comment made by Flavell about Piaget's schemes might be borrowed; alternative frameworks '... seem to come in all shapes and sizes' (Flavell, 1963, p. 54). What provides evidence of an alternative framework is consistency of explanatory response, but the range of content where consistency must be shown to count as evidence of an alternative framework, and not simply a minor misconception, needs to be identified by the researcher in each case. In the case of water displacement two major 'frameworks' can be anticipated; one where a student consistently uses weight explanations to justify predictions made about water displacement, and one where volume explanations are used. In this study consistency is defined within responses which relate to three problematic aspects of displacement volume which are discussed later.

METHOD

Design

A pre-test, post-test, delayed post-test controlled experimental design was used, with four weeks separating the post-tests. One of three equivalent mixed ability classes in a South Australian high school was designated the control group, one was taught by the OC method and one by the FR method. Teaching was completed in two separate fifty-minute lessons (both classes were taught by one of the researchers (C.D.)) and was followed in the next class lesson by the post-test. The same test instrument was used for all tests.

Test Instrument

The test incorporated the Piagetian conservation tasks which utilise two plasticine balls to stimulate students' prediction and explanation of the effect of

shape change on weight, volume, and displacement volume (Rowell & Dawson, 1983). To this test additional questions were appended which looked more closely at students' understanding of water displacement. Specifically three different aspects of water displacement were examined.

1 One of two balls of plasticine which had been adjusted to be of equal weight was squeezed into a sausage shape. Students were asked to say whether the water level rise produced by the ball and the sausage would be the same or different and were asked to give an explanation for the prediction.

2 Students were asked about the relationship of the volume of water displaced (as measured by water level rise) to the volume of the immersed object. They were asked whether the two were the same, or whether one was greater, and to explain their answers.

3 From one of two equal balls of plasticine a small piece was removed and replaced by an equal volume of lead. Students were shown that the two had very different weights but the same volume. They were then asked to predict whether the water level rise produced by the two balls would be the same or different, and to give an explanation.

Students operating an alternative framework utilising weight as the cause of water displacement were expected to give weight explanations (and not volume) in 1 and 3, and possibly in 2, though this was unlikely as the question asked specifically about volume. Students with a volume explanatory framework should give explanations based on volume to all three.

Teaching Using the Ordinary Conflict Method (OC)

Students were first reminded about weighing objects and the units of weight. Four objects (blue, red, and yellow cubes and a stone) were each weighed with the help of a student assistant, and the results recorded on the chalkboard. Two of the cubes (blue, yellow) had the same weight but very different volumes, two cubes (blue, red) had similar volumes but different weights. Students then listed the objects lightest to heaviest. A similar procedure was adopted to list the same objects in order of volume, volumes of the cubes being calculated and that of the stone being given.

Students were then asked to predict the relative rise of water level produced by the objects on immersion. It was suggested that if they wished they might look back at the weight and volume orders. Some students then gave their suggestions and reasons; only weight and volume ordering emerged. Students were asked to note the differences in the orders, and asked how many had picked each one. This ended lesson 1.

In lesson 2 the previous lesson was summarised and students referred back to their predictions of water level rise. The experiment was not done with the water rises being recorded, and students being asked to order them from smallest to greatest. They were also asked to privately compare this with their own predictions. If wrong they were to compare the water level rise table with the weight and volume tabulations to see if either of these better predicted the water rise. Following this a lump of plasticine was introduced. It was weighed and students recorded this and wrote a new order of weights for the 5 objects. Its volume was calculated after pressing it into a cube and it was placed into a new order of volume.

Students then individually predicted the new order of water level rise for the five objects and gave explanations for their predictions. Some of these were recorded and discussed. The water level rise produced by the plasticine was measured and the result compared with the predictions. Finally the series of experiments was discussed and summarised.

Teaching Using the Framework Replacement Method (FR)

While this method provided identical experiences for the students, the order of presentation differed, reflecting a five-step strategy (Rowell & Dawson, 1983, p. 214).

(a) Students were made consciously aware of their existing ideas.

Firstly, students were asked to consider the water level rise produced by an immersed object and to suggest what features of the object might be important in determining the amount of the rise. They were asked to record their thoughts individually.

(b) Different ideas were not discussed in detail or brought into conflict but accepted as equally possible solutions.

(c) Students were asked to retain their ideas, but were told that one possibility would be taught, and that their help would be needed later for its evaluation.

Students were informed that we were going to look closely at one of these explanations: that of the volume of the object. We were not saying it was an important factor but we were going to look at some experiments assuming that volume was important. Later they would be asked to look at this view and compare it with reality and their original view.

(d) The idea was taught linking it, where possible, to existing knowledge.

First students recorded the volumes of the four objects, and ordered them from smallest to largest. They were then asked to predict the relative water level rises produced assuming that volume was important. The experiment was done and the results compared with the predictions. Now the plasticine was introduced, its volume given, predictions about the water level rise made, and the empirical results compared with the predictions. By now it was agreed that the volume of the object was a good predictor of water level rise.

(e) Once students would use the new idea, the old ideas were recalled for comparison and both are compared with reality.

At this point, we returned to the alternative explanation that many students had given, that of weight. The four objects were weighed and ordered from lightest to heaviest. A comparison of this list with the water level rise table showed that the orders were different. The plasticine was now introduced, and again it was found that its weight was not a good predictor of the water level rise it produced. Finally the series of experiments was discussed and summarised.

RESULTS

Responses by all students (control plus experimental) to the pre-test questions showed that, as expected, a considerable proportion (43/69) gave some weight-based explanations for predictions made. However, the degree of consistency in the use of weight arguments was low and only 13/69 gave firm evidence of a consistently weight-based 'alternative framework'.

In the delayed post-test nine students utilised a weight-framework (seven of these did not do so on the pre-test) and 25 a volume-framework. All ten students giving evidence of a volume-framework on the pre-test retained that on the delayed post-test.

In view of the purpose of the experiment, to investigate framework replacement, it was important to follow the progress of the 13 students who began with a weight-framework. Three were in the OC group, eight in the FR group, and two in the control group. Three of these students (one OC, two FR) showed evidence of a total framework replacement, giving consistent volume explanations in the delayed post-test. Two students (one control (no delayed post-test), one FR) showed no change. All the others showed less structurally organised responses with a combination of weight and volume explanations, or uninterpretable in these terms.

What is evident in these results is that, though some students did operate a consistent framework, and though rapid framework replacement did take place, neither was very common. More commonly, lack of consistency and slow changes in understanding were observed and it is this aspect of the results which is illustrated in Figure 1 where the progress of all students who gave a weight explanation in the weighted ball question on the pre-test is followed (though other groups could have been selected to show similar patterns of progress). In Figure 1 an operative weight framework takes the form WWW or W-W and a volume framework VVV.

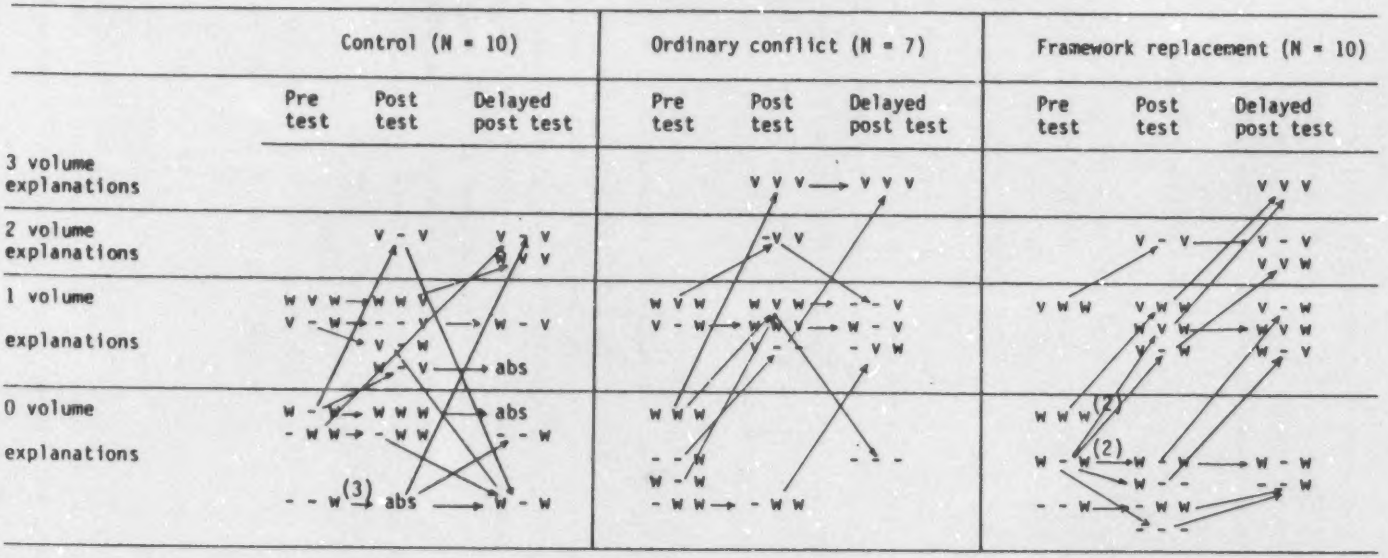
DISCUSSION

This study had the particular aim of using conflict methods to effect total framework replacement. While this did happen (three cases in Figure 1), such a change following this short intervention was infrequent. A major factor to consider here is that very few students (11 in the experimental groups) gave evidence of a consistently operative weight framework at the start of the experiment, hence the number of 'potential customers' was few (this was disappointing in view of earlier work with Year 9 students). Nevertheless, the teaching methods adopted here had no striking effect on these students, and progress was characterized more by gradually increasing understanding than by rapid framework displacement.

Further, despite the focus of the teaching sequence being on one particular aspect of displacement - that of the possible relationship of the attributes of the object (weight and volume) to the water displaced, understanding of other aspects of displacement volume were just as likely to be the first to show a volume explanation: there was no evidence at all that students were giving verbally learned answers to the weighted ball question. As the focus of the teaching sequence had been solely on this particular aspect, it was initially hypothesised that its understanding might be transferred to other aspects, thereby allowing the student to rapidly generate a volume-framework. That the teaching led to unpredictable progress in any of the three aspects of displacement volume tested indicates that experiences which we deemed critical for understanding one of them may instead have assisted some students to understand other aspects. There was no one-to-one relationship between what was taught and what students learned.

As discussed earlier, the term 'alternative framework' has been used widely, though often without a specific definition of what is to be understood by this when applied to a particular content area. For Year 8 students 'alternative framework' seems to imply a far greater degree of consistency than is apparent for most students at least in this content area.

FIGURE 1 PROGRESS OF STUDENTS GIVING A WEIGHT EXPLANATION TO WEIGHTED BALL PROBLEM IN PRETEST ON THREE ASPECTS OF DISPLACEMENT VOLUME*



* The three records for each student show the type of explanation for each of the three aspects of displacement volume.

1. equality/inequality of water displacement by sausage and ball.
2. relationship of volume of water displaced to object volume.
3. volume displaced by weighted and unweighted balls.

W = weight explanation V = volume explanation - = no explanation or other.

A further aim of this study was to investigate the relative effects of two different conflict methods. Because of the small numbers involved in making any particular change this is difficult to do, but in general terms it appears that the methods were about equally effective. However two possible differences were noted.

Initially several students who conserved weight but not internal volume (comparison of the volumes of a plasticine ball and a sausage made from a similar ball) also conserved displacement volume, reasoning that because the sausage and the ball had similar weights, they would create the same water level rise. However on the post-test and/or delayed post-test, the fact that it is the volume of an object which determines the amount of water displaced was recognised and was integrated with the failure to conserve internal volume. Hence students responded that the water level rise caused by the ball and sausage would be different as the two had different volumes. Interestingly, of the students who potentially could show this change (i.e., initially failed to conserve internal volume and gave a weight explanation for equality of displacement by sausage and ball) 1/7 of the OC group and 7/13 of the FR group actually showed it, suggesting that perhaps the latter method was rather more effective in promoting such logical interrelated understanding.

A further small difference in results is shown in Figure 1. Between post-test to delayed post-test, 2/7 students in the OC group showed an increase in the number of volume answers given, and two also showed a decrease. In the FR group however, 5/10 students showed an increase in the number of volume explanations whereas no student showed a decrease. An earlier study on teaching control of variables by the two methods used here, (Rowell & Dawson, 1984) showed somewhat similar results with stability and even improvement of framework application between post- and delayed post-tests being more in evidence in the FR group.

Implications for Teaching and Research

Watts (1983) has stated that 'by better understanding the beliefs and commitments of pupils about the concept of force, the teacher has a firmer basis from which to choose particular teaching approaches'. But such beliefs and commitments are held by individuals not class groups: as Watts (1983) said 'a framework is a composite picture based on ideas shared by a number of pupils'.

Such artefactual structures are no basis on which to develop conflict related teaching strategies; strategies which, with the concept of equilibration at their core, must focus on individual learners. Rather the teacher would need to identify individual understandings and devise individualised sets of learning experiences designed to provoke conflict for each student - a major, if not impossible, task.

The FR strategy recognizes this dilemma. Its concern is to provide each individual in the group with the same coherent well understood framework which is in potential conflict with any and all of their individual, idiosyncratic, relevant prior conceptions. Individual problems are then resolvable by individuals. What teachers must attempt is to raise as many as they can, to stimulate students to do the same, and to require solutions and explanations. As may be seen the FR strategy differs little from normal good teaching approaches except at the very beginning and at the very end.

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Research in Science Education, 1984, 14, 78-88

SOME STUDENT CONCEPTIONS BROUGHT TO THE STUDY OF STOICHIOMETRY

Ian Mitchell and Richard Gunstone

OUTLINE OF THE STUDY

This paper reports the views of students found as part of a wider study conducted mainly in the first author's Year 11 Chemistry classrooms. The study originated from an interest in the views students bring to science classrooms and the effects these have on subsequent learning. The term 'Children's Science' will be used to label these views.

Students in introductory chemistry courses always find stoichiometry and the mole concept very difficult (Kierks, 1981a, 1981b). It was hypothesized that hitherto unsuspected children's science may contribute significantly to these difficulties. The study set out to identify any relevant children's science and then to design instruction which would attempt to take account of such views.

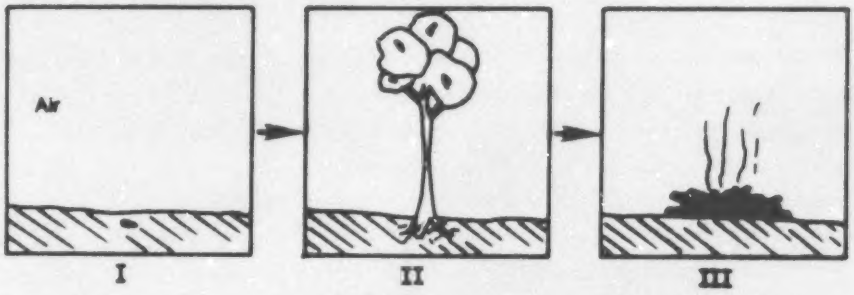
Initially the models, concepts and skills involved in stoichiometry and related areas were analysed and organized into a hierarchy. This analysis was then used to design a written Pre-test which was administered to the first author's 1982 Year 11 Chemistry class. The results were used to place the class roughly on the hierarchy and to assist in designing a set of cards for clinical interviews. Six students were chosen to represent the full range of scores on the test and interviewed for 45 minutes each (the Pre-Interviews). These interviews were taped and the results used to design an instructional strategy different to the fairly traditional one previously used by the first author. Stoichiometry was taught using this new strategy and the class tested with a fairly traditional achievement test. A follow up interview, (the Post-Interview) was designed and the same six students were re-interviewed to attempt to determine the effect of the instruction on their children's science.

The instructional strategy was then modified in the light of the Post-Interviews, the test results and the experience of teaching it. This modified strategy was used the next year (1983) at another school by the first author. The views of the 1983 class were investigated before instruction with a written probe which explored some of the areas where substantial misconceptions were found in the 1982 class. These views were used as part of the 1983 instructional strategy.

PROBES OF CHILDREN'S SCIENCE USED IN THE STUDY

The 1982 Pre-Interviews were intended to probe a number of issues: whether students have well formed views in several areas; whether students have some key chemical concepts and, if so, how they use them; how students analyse situations involving physical and chemical change; what meanings students give to some chemical labels. The basic technique was a mixture of the Interview about Instances and Interview about Events techniques described by Osborne and Gilbert (1979) and Bell and Osborne (1981). Cards describing appropriate situations were used as a focus for an open-ended discussion whose direction was largely determined by what the student said. A typical card is shown in Figure 1. The questions were initially covered and were revealed and discussed one at a time.

CARD 7



7 A large glass box is constructed, soil added, and a seed planted (Box I). Three years later a tree has grown (Box II). This tree is then chopped down and burnt (Box III).

a) In your opinion, comparing I, II, and III, what changes, if any, have occurred in -
   i) the total mass in the box;
   ii) the total number of atoms in the box;
   iii) the total number of molecules in the box;
   iv) the total number of carbon atoms in the box.

b) Where did the atoms in the tree come from?

FIGURE 1

Card 7 of the Pre-Interviews

Due to the 45 minute time limit not all cards were discussed with all students.

The 1983 written questionnaire used the situation described in Figure 1 along with three others. Each situation was presented orally and the whole class made written responses to a few questions similar to those in Figure 1. It should be stressed that the primary purpose of this questionnaire was associated with student learning, not data collection. It was a fairly successful attempt to confront students with their own views. Its purpose was carefully explained to distinguish it from an instrument of assessment. It probes a fairly small area and hence relies on some knowledge of likely views. This means it could not have been written in 1982. It is felt that the questionnaire was neutral in the sense that it would not create the expected misconceptions, although it was expected that it might weaken some. It is also felt that results from both the interviews and the questionnaire are conservative, in that neither reveal all of the misconceptions of any of the students.

As is usual during clinical interviews, the interviewer often found several responses which warranted investigation. It was not always possible to discuss all of these in the time available, hence some misconceptions were almost certainly missed. The questionnaire allowed for no follow-up at all. It only identified the models and views that students chose to use in their fairly brief explanations.

Interpreting both probes involves the usual difficulties arising from attempts to separate and classify what is a continuum of views, and from attempts to produce models to represent the ways students describe the world.

The 1983 questionnaire did not reveal any major new misconception in the area probed. However, it did produce some new variations of the ones identified in 1982.

TERMINOLOGY

For the purposes of this study, 'stoichiometry' includes all problems involving the use of the mole and 'Misconception' refers to a discrepancy between children's science and scientist's science.

RESULTS

Table 1 summarizes the 1982 Pre-Interview results. It attempts to collapse the range of student views into six categories. A X indicates a student showed reasonable evidence of the particular misconception, a √ indicates reasonable evidence that the student did not have that misconception (though the view may not be perfect scientist's science), ½ means the student showed the misconception in some situations but provided a correct analysis in others, and ? means insufficient evidence is available for any reasonable inference. The stude[illegible] were interviewed in the order

A to F and the interview was modified slightly after A. The number in brackets is the student's score on the achievement test at the end of the unit.

TABLE I

Summary of Pre-Interview Results

Misconception	STUDENT A (80)	B (47)	C (85)	D (100)	E (0)	F (27)
I Matter is not made solely of discrete particles	✓	✓	✓	✓	x	✓
II Misuse or misunderstanding of the concepts and/or labels - atom, molecule, element, compound	✓	x	✓	✓	x	x
III Non-conservation of atoms and/or mass	✓	x	½	½	x	x
IV Confusion between the conservation of atoms and the possible non-conservation of molecules	x	x	✓	✓	x	x
V The equation is not seen as giving the reaction ratio	✓	½?	½	✓	x	x
VI Equations are not called for	x	x	x	x	x	x

These six misconceptions are now considered in more detail.

Misconception I: Matter is Not Made Solely of Discrete Particles

It appears likely that few students see matter in all situations as being composed entirely of particles with no other substance between them. No student has been identified as having a completely continuous view of matter, although Student E came close. When discussing a rusting nail he said a nail atom would be 'changing to a rust atom'. Then later in the interview we had:

T: 'When you said a rusting nail was changing from a nail atom to a rust atom, what's happening to the atom when it does that?'

S: 'It's changing'.

T: 'What about it is changing?'

S: 'Ah - the appearance'.

From this and other comments, we infer that he had a continuous, rather than particulate, view of matter. Atoms and molecules appeared to be grafted unsatisfactorily onto this continuous view. When probed with Card Id (melting fat), we had -

S: 'Ah ... the molecules inside which are holding it together as a solid ... they're dispersing as a gas and ... the fat's going into a liquid'.

In the Post-Interview Student E showed aspects of this view when he said iron atoms (when rusting) were 'decaying'. Five to seven of the students at Laverton thought atoms decomposed as a corpse decayed.

However, most students investigated seem to make some use of particles in their model for matter.

Misconception II: Confusion between atoms and molecules

Three of the six interviewees (B, E, and F) were unsure of the difference between these terms. B and E tended to use them interchangeably, F selected o + o → O as a better illustration of '2 atoms → 1 molecule' than o + o → ∞. He saw atoms as losing their identity when combined into molecules. He also saw all chemical reactions as involving atoms combining or coalescing into molecules.

This was not formally probed, but class discussion revealed several students with similar misconceptions.

Misconception III: Non-Conservation of Atoms and/or Mass

This appears to be very widespread. Very few students see atoms as immutable and hence they do not see mass as conserved in chemical reactions (or in several physical changes). Of the six interviewees, only Student A did not show this view and it was felt during the interview that he changed his views on mass after being asked first about atoms. Student C showed considerable confusion when asked about some burning charcoal in a sealed glass box. In discussing the weight of the box he said 'It will stay approximately the same, but it will become less'. [Why?] 'Because of the energy used up in the actual reaction'. When asked about a tree growing in a box, Student B revealed non conservation of atoms in the Post Interviews:

T: 'Where did the atoms in the tree come from?'

S: 'They're made from seed, seedling'.

T: 'Uh huh ... the seed is making new atoms'.

S: 'Yes'.

Non conservation of atoms and mass was the focus of the 1983 questionnaire. This misconception was very widespread. Table 2 summarizes the results. In each situation a chemical change was described as occurring inside a perfectly sealed but not insulated box. The box was transparent in the growing tree situation. In each case students were asked whether the mass of the box would increase, decrease, or remain unchanged. A follow-up question, designed to gather some information on the models students were using, was asked. Then all the situations were presented again and the students asked about the number of atoms in the box. In every situation, the follow-up question identified several students who had made apparently correct choices by using incorrect models. Hence the last column of figures in Table 2 shows the number of students who appeared to be using a chemist's model.

Table 2 shows a very widespread belief in non-conservation of atoms and mass. When presented with the same set of situations, 40 per cent of a class of science graduates with at least two years of chemistry showed non-conservation in at least one of these situations.

Apart from non-conservation of atoms, 2 other broad reasons are often used by students to support non-conservation of mass views. These are labelled Misconception III[1] and Misconception III[11].

TABLE 2

Results of 1983 Questionnaire

	Mass of system			Number of atoms			Correct model
	Increase	Decrease	No change	Increase	Decrease	No change	
Growing tree	13	-	4	13	-	5[a]	2
Burning wood	-	13	4	1	7	8	1
Decaying corpse	1	8	8	-	8	9	3 - 5[b]
Man eating & exercising	1	6	10	1	2	14	4 - 5

a: one student circled both alternatives

b: some student responses were unclear

Misconception III[1]: Gases have Little or No Mass

At least four of the 1982 interviewees displayed this misconception. In 1983 one student stated gases have no mass in explaining the combustion situation, and seven indicated this in the next situation (the decaying corpse). This suggests again that results given in this paper are most probably conservative.

Misconception III[11]: The Nature of Chemical Energy

This issue was not initially seen as relevant to stoichiometry and was not probed in the Pre-Interviews. During the Post-Interviews the interfering concepts non-conservation of atoms and massless gases were less prominent. However, another issue became prominent in 'supporting' non-conservation of mass. It became apparent that none of the students had a model of chemical energy which did not involve either the destruction of atoms or the existence of energy as a separate component of matter. To date we have not identified any student who does not use one of these models. This was an unexpected discovery of the Post-Interviews.

Two possible reasons for this appeared. One was Einstein and $E = mc^2$. This was not mentioned specifically, but several students referred to mass being lost as, or turned into, energy. The other, quoted by two students, was the equation seen in Biology: Glucose + Oxygen → Carbon Dioxide + Water + Energy. Written in English like this, as it often is, Energy appears to be a substance essentially co-equal with the reactants and products.

During the Post-Interview Student F showed the apparent influence of Biology teaching in this area. When discussing a man breathing with a large sealed plastic bag over his head the following exchange took place.

S: 'There'll be some change in mass, but very slight, due to the sort of ... he's respiring and that's using energy so ...'

T: 'Why will that use some mass?'

S: 'Because, ah, glucose and the energy's getting used up'.

He then said there will be no change in oxygen atoms in the [bag + lungs] and atoms of all kinds in the [man + bag + lungs]. These answers conflict with the previous one. The equation $C_6H_{12}O_{6(aq)} + 6O_{2(g)} \rightarrow 6CO_{2(g)} + 6H_2O_{(l)}$ was given and briefly discussed.

S: 'Shouldn't that be plus energy'.

T: Add '+ Energy' to the right hand side.

Here, as mentioned, the student has been influenced by Biology and appears to see 'Energy' as another product.

T: Then asked if the R.H.S. would weigh less than the L.H.S.

S: '... I think it'll weight slightly less because of the process involved in ... carrying out the ... '.

Among the students at Laverton in 1983, eight or nine said the sun's energy was converted into mass or atoms or both during photosynthesis and seven said some mass was converted into energy during combustion. When discussing a man eating and then exercising in a sealed room, four or five felt some mass was converted into energy, and six or seven stuck to conservation of atoms but appeared to be aware that this left them with no explanation for the chemical energy in food.

Misconception IV: Confusion between Conservation of Atoms and Non Conservation of Molecules

As expected, students B and E of the 1982 sample made no distinction between atoms and molecules, while F thought neither was conserved. Student A, who made no errors in using the two terms and showed reasonable conservation of atoms, thought molecules would always be conserved. Informal discussion showed considerable confusion on this issue.

Misconception V: The Equation is Not Seen as Giving a Reaction Ratio

When given an equation in the Pre-Interview to describe the situation under discussion, only students A and D used it entirely correctly to obtain the reaction ratio. Students E and F could make no use of equations, and E showed an interesting view of the term 'balanced equation' in the Post-Interview when discussing the man breathing in a plastic bag. He had originally said (correctly) that there would be a drop in the number of oxygen molecules. However, when he was later presented with the equation:

$C_6H_{12}O_{6(aq)} + 6O_{2(g)} \rightarrow 6CO_{2(g)} + 6H_2O_{(l)}$ we had -

S: 'Ah ... No, I'm not sure ... I don't know'.

T: 'Well, you said there'd be a drop in oxygen molecules'.

S: 'Now I think there wouldn't be ... I think they'd stay the same after looking at that'.

T: 'Why?'

S: '... 'cause it's a balanced equation ... same amount which goes in must come out I suppose'.

Misconception VI: Failure to Call for an Equation

None of the students called for an equation in situations where one was needed in the Pre-Interviews. However at the time it was felt that this was due to their relative inexperience in discussing and using equations to analyse chemical changes. During the Post-Interviews it was realized this assumption was incorrect.

We found the extent of VI to be literally unbelievable; students just would not call for equations, no matter what hints and prods they were given. The following exchange occurred with Student C, one of the best students in the class, as part of the response to the man breathing in the plastic bag.

S: [Having reasoned the mass of gas will go up]
'Yeah! Well, granted that the same number of carbon dioxides going out as the oxygens coming in'.

T: 'O.K. is there any other information that you need?'

S: 'Well, apart from that, no'.

T: 'Apart from what?'

S: 'Apart from the fact that you don't know how many are the rate of going in and coming out'.

A few more exchanges follow and then we have:

S: 'Yeah, the number of oxygen atoms will decrease, because we're taking oxygen molecules into the bloodstream which is two oxygen atoms ... oh, wait a minute, it won't change because, as we're taking two in ... assuming, of course, that we're taking the same number out again, we get two oxygen atoms in any oxygen molecule and also two in a carbon dioxide molecule'.

T: 'Is there any information which could give you this important ratio of oxygens in to carbon dioxide out.'

S: Very long pause during which he is clearly thinking hard; he gives no response.

The student has realised he needs the ratio of reactants to products but, in spite of heavy prompting, he will not call for an equation. He was then given one and used it quite correctly. A similar exchange occurred on the next card, where he again did not call for an equation.

This exchange was not at all extreme, but occurred with most students on more than one card. Student D, the top student on the Post Test (100%), called for an equation on Card 5, after failing to call for one on either Cards 3 or 4, and eventually being given one on Card 4. This was the only example of an equation being called for, even though students were all given an equation to Card 4 and, in most cases, to Card 3 also. Every problem the students had encountered during the instruction had included an equation. Balancing and the meaning of suffixes and prefixes had been stressed, and using ratios derived from the equation was a central step in the problem solving procedure.

CONCLUSION

Two issues are important in considering the children's science identified in this study. Firstly, the modes of data collection make it very likely that the prevalence of particular views is underestimated. Secondly, the initial focus on stoichiometry has very likely influenced what particular children's science has been elaborated. That is, had we started with a focus on bonding we would expect to have found an overlapping but not identical set of views.

It seems clear that the achievement of a purely particulate model of matter is far more difficult than is generally assumed. An understanding of a number of areas of science - e.g. heat, energy, stoichiometry, chemical reactions - depend on it. Conservation issues are closely related also. We see three critical issues in considering particulate models and conservation. Conservation of atoms underlies conservation of mass (although the reverse is often implicit in teaching). Most chemical changes children see involve the apparent disappearance or appearance of matter. (Students rarely grasp the role of colourless gases in several of these changes.) A model of chemical energy is needed to make particle/conservation concepts appear plausible. It is not until the latter two of these issues (apparent non-conservation of matter, chemical energy) are established that the differences between atoms and molecules can be treated and related to non-conservation of molecules.

Chemists see chemical reactions as a rearrangement of immutable atoms into allowable molecules. This is crucial to stoichiometry and relies on all the concepts just mentioned.

The other major issue to emerge from the study is that the need for and role of equations in stoichiometry is not integrated into the cognitive structures of even the most successful students in the way we have previously assumed.

Finally it should be noted that the observably high correlation between 1982 student scores on the achievement test and their initial children's science (see Table 1) indicates that the overcoming of the identified misconceptions is likely to be critical to the mastering of stoichiometry.

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TEACHING AND LEARNING IN HIGH SCHOOL BIOLOGY LABORATORY CLASSES IN ISRAEL

Yael Friedler and Pinchas Tamir

Sharp criticism has been levelled at previous research studies dealing mainly with regard to the limited scope of these studies and their research methods, which were not suited to the special features of laboratory teaching (Blosser, 1981; Hofstein & Lunetta, 1982). In light of this criticism and the awareness of the complexity of laboratory teaching we chose a number of strategies, so that each of them would be able to verify the results obtained by the others.

As the framework for our research we used the model suggested by Hegarty (1979). The advantages of this model lie in the detailed categories, the operational definition of variables and in the suitability to the teaching-learning process in the laboratory. We were concerned only with those parts of the model dealing with the laboratory, and excluded the theoretical lessons. Since the biology curriculum in Israel is inquiry oriented, scientific inquiry was chosen as a main focus of the study.

Purpose of Study

The aim of this study is to describe the teaching and learning practices in biology laboratory classes in Israeli high schools. According to our model, we defined four objectives which were derived from the main aim:

a) Analyzing the planned activities as presented in the laboratory manuals. (The intended curriculum)

b) Examining the importance and degree of achievement of different instructions objectives in the laboratory as perceived by teachers and students in high school. (The perceived curriculum)

c) Describing and analyzing the activities actually taking place in the laboratory. (The implemented curriculum)

d) Assessing the outcomes of the learning as exhibited by the students' achievement on laboratory tests. (The achieved curriculum)

METHODS

1 The planned activities in the textbooks commonly used in schools were content analyzed to establish their level of inquiry (based on Herron, 1971) and the inquiry activities (based on Tamir & Lunetta, 1978). Additional features of the laboratory manuals such as layout, distribution of questions in the text, clarity, drawings, and diagrams, were also studied. Altogether 12 biology textbooks were analyzed.

2 Perceptions related to instructional objectives in the laboratory were examined by questionnaires, in which teachers (N=62) and students (N=221) were asked to rate each of 31 objectives, a) with regard to its importance and, b) with regard to the extent to which it was achieved in their classes. In order to increase the teacher sample, an additional questionnaire which included eight main objectives was mailed to another group of teachers (N=93). Altogether we had responses from 155 teachers. The teachers were also asked to indicate what reasons would account, in their opinion, for any gap between the rating of the level of importance and the degree of actual achievement.

3 Description of the activities actually taking place was done by observations in 75 laboratory lessons (160 hours) in six different schools (religious girls only, rural, developing town, three city), in Grades 9 to 12. Observations were conducted with the aid of a special observation instrument, developed as part of this research project, which focussed on the inquiry components of the lesson (see Appendix I). The structured observations were accompanied by interviews with students ('open observations') in which the difficulties they encountered during the lessons were assessed. The observers filled an additional form at the end of the lesson, in which they provided information concerning the frequency and location of laboratory lessons at various grade levels, the presence and role of the laboratory assistant, the use of teaching aids, the use of instruments and tools in laboratory work, as well as the number of students and their grouping in the lesson. In addition, teachers and students were interviewed about their attitude towards laboratory lessons. Frequency of homework assignments was checked, and the written homework was analyzed to establish their demands for inquiry skills and the students' mastery of these skills. The analysis of the homework questions was done by a method similar to that used in analyzing the inquiry activities in the textbooks (see 1. above). Analysis of student answers was done by a method similar to that used in the analysis of the matriculation examinations (see below).

4 Assessment of the outcomes was done by analyzing a sample of laboratory matriculation examinations in the years 1980-1983. There are great advantages in using existing matriculation tests:

a) the tests already exist;

b) information is collected from a large population;

c) the tests are a 'natural' part of the educational system, hence the teachers and the students do not perform 'specially' for the researcher.

In analyzing the questions, we identified the demands for inquiry skills, in a method similar to that used in analyzing inquiry activities in the textbooks. In analyzing the answers we checked the difficulties students encountered in those skills, with the aid of the tool used for evaluating matriculation examinations in this country, which includes a list of inquiry skills, for each of which the various expected levels of answers are listed (Tamir, Nussinovitz, & Friedler, 1982). For a number of skills (defining a problem, formulating a hypothesis, planning an experiment, reporting data) we conducted a more detailed analysis of a limited number of examinations, as we wanted to study in depth the difficulties students have with these skills. There are three unique features to our method:

a) Combining a number of sources of information about the teaching-learning situation in the laboratory.

b) Developing an observation strategy based on a combination of structured and open observations.

c) Analyzing matriculation tests. We believe this method has potential generalizability for other studies.

MAJOR FINDINGS AND MAIN CONCLUSIONS

1 Teachers rate the importance of learning scientific inquiry skills the highest among the clusters of learning objectives in the laboratory. Students rate it fourth (out of six). This difference hints at difficulties that teachers have in communicating the importance of scientific inquiry to their students.

2 A statistically significant difference exists for most objectives between the assigned level of importance and the rating of their achievement, the former being higher. Teachers explain this gap mainly in terms of administrative constraints, such as: budget cuts, insufficient instructional time, unsatisfactory work conditions (e.g., crowding in the labs), as well as by the need to adapt subject matter and teaching methods, in the eleventh and twelfth grades, to the requirements of the matriculation examinations.

3 Half of the laboratory exercises in the laboratory manuals commonly used in high schools are at level 1 of the inquiry scale (problem and methods provided to the student) and a third are at level 0 (problem, methods and even expected results are provided). The rest of the laboratory exercises (one-fifth) are at level 2 (only the problem is provided).

4 Forty per cent of laboratory lessons during the observation period took place in twelfth grade, 28 per cent in ninth grade, and very few (11%) in tenth grade. Most laboratory lessons (84%) occupied double periods (100 minutes). All took place in specially equipped laboratory rooms. In two-thirds of the observed lessons the number of students ranged between 11 and 20. The students worked in pairs in 50 per cent of the lessons observed, in groups of three to six in a quarter of the lessons and individually in a quarter of the lessons. In 97 per cent of the lessons a laboratory assistant was available to prepare the necessary equipment and materials. The tool most widely used was the microscope. Students were assigned homework in 86 per cent of the lessons. Evaluation of the students' performance in the laboratory, i.e. by a special laboratory test, was practically non-existent.

5 The potential of group work, as far as student enrichment, developing concepts and self-criticism are concerned, was not actualized. The verbal interaction among students in the groups was mainly on a low cognitive level featuring techniques and procedures such as: 'Put a drop of water', 'Bring the test tube', 'What do we have to do now?'. Teachers did not interfere with setting up work groups.

6 The laboratory matriculation examination was found to play a decisive role in setting up laboratory lessons and in shaping their nature.

7 The same texts were used in most laboratory lessons in all schools, especially in the ninth and twelfth grades.

8 Only a small part of the discussions in the lessons was devoted to inquiry processes. This part was larger in the twelfth grade than in the ninth grade. This finding can be explained by the fact that in the ninth grade most laboratory exercises are on inquiry level 0, while in the twelfth grade they are on inquiry level 2.

9 The rise in inquiry levels in laboratory lessons (especially those which followed the series 'Inquiry Oriented Laboratory Problems') was accompanied by an increase in the time needed for arrangements as well as that required for conducting the experiment, but very little additional time was devoted to discussion. These findings raise serious doubts about the meaningfulness of learning in these inquiry oriented laboratory lessons.

10 The following difficulties were discovered through the interviews (the 'open observations'): a distorted understanding of fundamental concepts (such as: cell, enzyme); inability to link theoretical knowledge to observed phenomena; inability to distinguish the relevant from the irrelevant in the experiment; misleading associations and deficiencies in knowledge, especially of chemistry related to biological processes. The value of problems in chemistry, especially in eleventh and twelfth grades, was also stressed by teachers in the interviews.

11 Students' achievement in the matriculation examinations was on the average very high. However, it was lowest in the following skills: defining a problem, formulating a hypothesis and planning an experiment. In addition we found difficulties in defining the variables and in the ability to plan systematically a complete experiment including controls, conditions, replications, etc.

12 All teachers and students who were interviewed considered the laboratory lessons to be an essential part of learning biology.

Many studies would end at this stage. However, we feel that it is important to translate research findings into action. Hence we designed an instructional module to deal with some of the difficulties which were identified.

In light of the findings which pointed at too little consideration of scientific inquiry in the textbooks as well as in the classes, and at deficient mastery of inquiry skills as evidenced by the students' answers to the matriculation examinations, a module entitled 'Basic Concepts in Scientific Research' was designed. In this module the text is accompanied by 'dry' as well as 'wet' laboratory tasks, constructed hierarchically according to skills. The goal of the module is to clarify the concepts problem, hypothesis and experimental design, while incorporating information and explanations about the historical and philosophical origins of these concepts, and about the way they are used and applied in scientific research. Furthermore, the module stresses the everchanging nature of scientific knowledge and the role of the scientist in formulating scientific theories and in creating scientific knowledge.

The module was tried and evaluated in seven eleventh and twelfth grade classes in six different schools. Evaluation was carried out by observation, achievement tests and questionnaires administered to the teachers and the students. Positive results were found concerning the students' mastery of the skills of defining a problem, formulating a hypothesis and planning an experiment and their application to solving inquiry problems. In addition the module was evaluated by experts including high school teachers, professors of biology and professors of history and philosophy of science. The module was revised on the basis of the comments offered by these experts and is now available to schools generally.

RECOMMENDATIONS

Based on our findings, we offer (in addition to the 'module treatment') the following recommendations:

a) Relevant chemistry chapters must be incorporated as an integral part of biology studies, especially in higher grades (elsventh and twelfth).

b) The laboratory matriculation examination should be re-examined, with the purpose of modifying its topics and its form. This should be done in order to prevent routine learning of inquiry skills which might create a distorted image of scientific inquiry.

c) The laboratory activities in the textbooks should be re-examined, with the purpose of:

   1 matching the topics of these activities to the level of students (especially in ninth grade);

   2 increasing the inquiry level of laboratory activities (especially in ninth and tenth grades);

   3 rewriting the theoretical material which is required for meaningful performance of the experiment and incorporating it in the text.

d) A substantial part of the preservice and inservice training of science teachers should be devoted to teaching in the laboratory.

Within this framework it is essential to:

1 explain to the teachers the aims and objectives of laboratory teaching and its importance, in each grade level;

2 clarify the concept of 'inquiry' while emphasizing the changing structure of knowledge and the role of creativity and intuition especially at the stages of defining the problem and planning the experiment. The module 'Basic Concepts in Scientific Research' can be very useful for this purpose;

3 provide opportunities to analyze laboratory exercises in textbooks so that the teachers learn to identify inquiry activities and inquiry levels, and consequently build lesson plans with an inquiry orientation and carry them out properly;

4 stress the complexity of the demands that laboratory lessons impose on teachers (preparing materials, trying the experiment beforehand, supervising the laboratory assistant, leading discussions, assigning a laboratory report and checking it), as well as on the students (they must be in command of relevant biological content, proficient in inquiry and manipulative skills and, in addition, able to apply them to the problem they try to solve). It must be stressed that the laboratory should be an integral part of the current curriculum. Each laboratory lesson should begin with an introductory discussion, aimed at clarifying the relevant biological content, the techniques and the inquiry skills involved in the experiment to be performed. Theory and practical work should be tied together. For this purpose post-laboratory discussions are essential as well.

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APPENDIX I

Some details about the method of the observation

The laboratory class was divided into three stages: pre-lab discussion, performance and post-lab discussion. The observations were carried out by two observers who observed simultaneously the pre- and post-lab discussions. During the performance stage one observer concentrated on the teacher and the other observer moved freely from one working group to another, staying with each group for 15 minutes. During the first 10 minutes the observer filled in the LOS observation sheet (time unit - 1/2 minute), shifting systematically each minute from one student to the next in the same working group. When all students in the group were observed, the first student was observed again. After 10 minutes the observer informally questioned the students in order to find out the students' difficulties in the specific lab.

The Laboratory Observation Schedule (LOS) contains the following categories:

PRE-LAB DISCUSSION*

1. Identify and formulate problems and hypotheses
2. Tie to previous lessons/ labs
3. Present theoretical background
4. Present facts and problems related to the design of the experiment
5. Talk about techniques
6. Predict results
7. Manipulate data

MISCELLANEOUS

1. Student talk-unrelated to the lesson
2. Students write in the notebooks
3. Students perform the experiment
4. Students read from the testbook
5. Student absent
6. Teacher illustrates
7. Teacher performs instead of the student
8. Teacher talk-administrative matters
9. Teacher talk-discipline
10. Teacher talk-unrelated to the lesson

PERFORMANCE*

1. Talk about techniques
2. Present theoretical background
3. Present facts and problems related to experiment
4. Manipulate data
5. Talk about the results
6. Interpret results, draw conclusions

POST-LAB DISCUSSION*

1. Manipulate data (reporting, making)
2. Talk about the results
3. Interpret results/draw conclusions
4. Talk about the experiment (variables, control, limitations)
5. Apply and make generalisations
6. Teacher gives instructions for the next experiment

* When not specifically stated the category may apply either to students or teachers.

The four main advantages of this observation method were: a) A simple way to gain a lot of information. b) Little disturbance to the ongoing lesson. c) Low cost. d) Immediate availability of the information for analysis.

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MODEL CONFUSION IN CHEMISTRY

Malcolm Carr

INTRODUCTION

Much of the discussion (e.g. Gilbert & Watts, 1983) of what have been variously labelled as preconceptions (Novak, 1977) misconceptions (Helm, 1980), alternative conceptions or alternative frameworks (Driver & Easley, 1978), and children's science (Gilbert, Osborne, & Fensham, 1982) has largely focussed on concepts with a discernible relation to everyday experience such as force, electricity, heat, light, particle, living and animal. Understanding of scientists' concepts is considered to be hindered by adherence to everyday understanding of these words and/or to an alternative set of explanations for phenomena associated with these words (Driver & Ericksen, 1983). Confusions and difficulties over a number of chemical concepts may require a different perspective, since these are abstract and formal explanations of invisible interactions between particles at a molecular level and are not likely to be arrived at from confrontation with the world of experience. Champagne, Klopfer, and Gunstone (1981) have suggested that interaction between 'prior knowledge' and formal instruction is more pronounced in mechanics than in other science subjects, and this view has been questioned (Gilbert & Watts, 1983). This paper examines the chemist's concept of acids and bases and suggests that students' difficulties in this area may be more usefully perceived in terms of confusion about the models used in teaching the concept rather than as a conflict between preconceptions and the scientific view. Such an analysis may be valuable for many other concepts in chemistry such as the mole, balanced equations, and even the nature of fundamental particles such as atoms, molecules, and ions.

CONCRETE TO ABSTRACT MODELS OF ACIDS AND BASES

The traditional approach is to begin with descriptions directly relating to sense data. Acids taste sharp or sour, they 'eat away' metals and change the colour of vegetable dyes. Alkalis or bases feel soapy and change the colour of vegetable dyes differently from acids. Finally an equation (which is often accurately recalled even by students who have had little interaction with chemistry) is introduced.

ACID + BASE → SALT + WATER

The next pedagogic model relates observation to invisible occurrences between particles at the molecular level. Such a molecular model is unlikely to have been pre-formed by the student, however intelligent, though chemists (including teachers)

who have successfully grappled with this abstract concept often behave in discussion and teaching as if students can 'see' chemical reactions in the same way as, e.g., they can follow the path of a thrown object.

ARRHENIUS AND LOWRY-BRONSTED MODELS

The modern model of acids and bases in terms of proton transfer reactions at a molecular level (Lowry-Bronsted) was formulated after a model which was, in some important respects, transitional towards a completely particle view (Arrhenius). The Arrhenius model has three main features:

(i) the description 'acid' or 'base' remains molecular in that it is applied to a substance which can exist in a bottle. Thus HCl, CH_3COOH and H_2SO_4 are acids because they dissolve in water to increase the concentration of H^+ ions, NaOH is a base because it dissolves in water to increase the concentration of OH^- ions. Acids and bases can be further classified as weak and strong.

(ii) the fundamental equation remains as

$$\text{ACID} + \text{BASE} \rightarrow \text{SALT} + \text{WATER}$$

(iii) The acid-base behaviour of solutions of salts requires complex argument based on hydrolysis. In terms of the equation in (ii) a salt is identified as being formed by reaction of a weak or strong acid with a weak or strong base. Thus, a solution of sodium ethanoate (acetate) is basic because it is a salt of a weak acid and a strong base. Arrhenius theory here is conceptually very difficult since many substances from bottles ('salts' such as ammonium chloride) dissolve in water to increase the concentration of H^+ ions but are <u>not</u> classifed as acids although they exactly fit the fundamental definition.

This difficulty is overcome in the Lowry-Bronsted model, which was formulated after the concept of ions in solids and in aqueous solution had been accepted in chemistry (a recent event historically). The significant features of the Lowry-Bronsted model are:

(i) the description 'acid' or 'base' is applied to molecules and ions. The latter category cannot have a separate existence in bottles. Acids are proton donors (HCl, CH_3COOH and H_2SO_4 as before, as well as NH_4^+, $H_2PO_4^-$ etc), bases are proton acceptors (OH^-, <u>not</u> NaOH as well as CH_3COO^-, HPO_4^{2-} etc). Aqueous acids are classified as weak and strong by reference to their relative abilities to transfer protons onto water molecules; bases are classified in a parallel fashion.

(ii) The fundamental equation changes to

$$\text{ACID}_1 + \text{BASE}_2 \rightleftharpoons \text{BASE}_1 + \text{ACID}_2$$

(iii) The acid-base behaviour of solutions of salts can now be described simply after a consideration of the ions present has been completed. Sodium ethanoate (acetate) solution is basic because the salt dissociates to hydrated sodium ions (which are neithr acidic nor basic) and hydrated ethonoate (acetate) ions which are weakly basic. Ammonium chloride solution is acidic because the solution contains ammonium ions (weak acidic) and chloride ions (neither acidic nor basic).

The differences in the two theories are sufficiently important to be worth tabulating.

Arrhenius	Lowry-Bronsted
Substance in bottle view. NaOH is a base	Molecules and ions view. OH^- in NaOH is the base
Acid + Base → Salt + Water	Acid + Base → Base + Acid
Complex theory of hydrolysis of salts	Hydrolysis of salts clear extension of theory

MODEL CONFUSION

Students learning about the chemist's concept of acids and bases will develop most of their understanding from experiences in laboratory, in the classroom and in textbooks. The task of comprehension will be more diffiuclt if transition from model to model is not carefully sign-posted. Very fundamental words and ideas change their meaning in proceeding from the Arrhenius to Lowry-Bronsted model. If we reflect that the process of changing paradigms in science has caused confusion and dissent (Kuhn, 1970) we should further reflect that changing models is not a facile procedure. Clear indications of <u>when</u> a new model is being introduced, of <u>how</u> this new model differs from previous models and of <u>why</u> the new model works better would seem to be vitally important in the teaching process. In the case of acids and bases there is all-too-clear evidence of model confusion from text-books used widely in secondary schools and in universities. Not only are the models of Arrhenius and Lowry-Bronsted not clearly separated (so that <u>when</u> the new model is being used is unclear), the fundamental difference between them (the <u>how</u> they differ) and the greater usefulness and coherence of the new model (the <u>why</u>) is not explicated.

A TEXT-BOOK EXAMPLE

The text recommended to first year students in several New Zealand universities, and widely overseas (Brady & Humsiton, 1982) provides a typical example of the treatment of acids and bases in many texts at this level, a treatment which is followed at a less difficult level in many secondary school texts. In Chapter 6 the topic is introduced using an Arrhenius definition, hence defining NaOH as a base. In Chapter 14, devoted entirely to acids and bases, the Arrhenius definition is repeated followed by the Lowry-Bronsted definition.

In a clear account the exemplars are mostly molecular species and the status of NaOH is not reconsidered. Rather an extension to other solvent systems is discussed (dealing with the why of this model since an important feature is the generalisation to solvent systems other than water) and this discussion leads to yet another acid-base model, the Lewis definition of acids and bases. (This latter model should, in my view, only be introduced to pupils who have understood the Lowry-Bronsted model, since it introduces further confusions too extensive to outline in this paper.) Chapter 15 of the text deals with acid-base equilibria in aqueous solution. Early (p.464) we find the statement 'Metal hydroxides are strong bases - they are completely dissociated' applied to NaOH solution. An Arrhenius model view. Next 'weak electrolytes include weak acids and bases' which is incorrect, confusing and based on the Arrhenius model. This statement is contradicted (p.471) when sodium acetate (which contains the weak base, acetate ion) is correctly stated to be completely dissociated (a strong electrolyte). Now follows a Lowry-Bronsted model discussion of polyprotic acids and buffers. In the section on hydrolysis (pp.480-86) the model returns to the Arrhenius view and salts are considered in terms of a 'hydrolysis constant' (p.482) indistinguishable from the Lowry-Bronsted 'base ionisation constant' defined earlier (p.466). The treatment of hydrolysis is complicated and confusing. It is salutary to quote here from a text published in 1949 (Philbrick, Holmyard, & Palmer).

> One advantage of the modern view (Bronsted-Lowry) is the great simplification possible in the explanation of salt hydrolysis. We can say that sodium acetate yields an alkaline solution simply because it contains a base, acetate ion, and ammonium salts give acid solutions because they contain an acid, NH_4^+.

The Chapter ends with a discussion of titrations and indicators which continues an Arrhenius view of hydrolysis of salts at the equivalence point (pp.487-492.

In the problems at the end of the chapter (15.35) students are asked about 'a weak base BOH'. Here the authors are purely Arrhenius again, since they require the base to react $BOH \rightleftharpoons B^+ + OH^-$ whereas Lowry-Bronsted treatment would be $BOH + H^+ \rightleftharpoons BOH_2^+$.

Another textbook (Chang, 1984) used widely in universities displays a confusion between Arrhenius and Lowry-Bronsted models which is even more extreme. After a treatment of the Lowry-Bronsted model the hydrolysis of salts is considered from a muddled Arrhenius view. One sentence will illustrate the confusion students would have with this treatment (p.457). 'Since NaOH is a strong base, Na^+ is an extremely weak conjugate acid; therefore, it has no tendency to react with H_2O to form NaOH and H^+ ion'. The first statement is Arrhenius, the second can only be seen as Lowry-Bronsted (as well incorrect).

A similar analysis of many texts shows the same switching from model to model. The texts display model confusion. Teaching relying on these texts as sources will escape the same confusion only if it is clearly recognised and avoided.

A notably clear exception to this model confusion in textbooks is provided by an Australian text also used in secondary schools in New Zealand (Stranks et al. 1970). The treatment is clearly and consistently Lowry-Bronsted. It is unfortunate that tertiary level texts may confuse this basically sound preparation.

STUDENT PERCEPTION AND PERFORMANCE

Students in secondary school perceive acids and bases to be a difficult topic (Burns, 1982). Students felt that their understanding of ionic acid-base equations was poor (ranked third poorest of the 50 topics surveyed). In interviews with late secondary and first year tertiary students (Note 1) only about a quarter of the sample of 24 appeared convinced that aqueous hydrogen chloride contained ions, and some of these students did not consider the acid to be fully dissociated. This reluctance to accept ions may stem in part from reluctance to abandon Arrhenius views, since molecules are saved in that model. The Lowry-Bronsted model requires that ions are recognised as important components of aqueous solutions.

In a recent national examination for students terminating secondary school in New Zealand (Universities Entrance Board Bursaries Examination in Chemistry, 1981), the author formulated a question on the 'hydrolysis of salts' which was

considered to be simple to answer from a Lowry-Bronsted viewpoint, but which would be much more diffiult from an Arrhenius viewpoint.

The question asked that students list the species present in a 0.1 mol l^{-1} aqueous solution of sodium ethanoate (acetate) and that they choose the approximate concentration of each species from (i) 0.1 mol l^{-1} (ii) 10^{-5} mol l^{-1} and (iii) 10^{-9} mol l^{-1} given that K_b for ethanoate ion was 10^{-9}. A Lowry-Bronsted perception of this system leads to the understanding that the solution contains $Na^+(aq)$ and $CH_3COO^-(aq)$ ions, and that a small proportion of the latter ions (which are a weak base) react

$$CH_3COO^- + H_2O \rightleftharpoons CH_3OOH + OH^-$$

An Arrhenius perspective will argue in terms of substances in bottles rather than separated ions. Analysis of the responses is not yet complete but a random sample of 24 students in the top octile showed that Arrhenius views were used by one third of these candidates, using equations such as:

$$CH_3COON_a + H_2O \rightleftharpoons CH_3OOH + Na^+ + OH^-$$

$$CH_3COON_a \rightleftharpoons CH_3COO^- + Na^+$$

to begin their answer. A quarter of these 24 students concluded that there was approximately 0.1 mol l^{-1} of CH_3 COONa in the solution. This latter statement could be made by a student who confused weak electrolytes and weak bases, a view reinforced by many discussions of Arrhenius bases. This question was the most poorly answered section of the entire paper.

THE HISTORICAL APPROACH TO TEACHING

This pedagogic method often traverses several models in arriving at the most recent, and has the merits of acquainting students with the development of a concept, and of revealing science as a progression through models which have been subjected to experimental criticism. From the perspective of model confusion the pedagogic method has very clear dangers since concepts from one model can all too easily be retained after they should have been discarded. It is particularly important when teaching an historical sequence of ideas that changes in models are clearly signposted and that danger signals are displayed.

CONCLUSION

This paper has been a preliminary discussion of model confusion about acids and bases, presenting evidence (some of it to be elaborated) that the Arrhenius and the Lowry-Bronsted models are confused in some textbooks, and in many students' minds.

A similar analysis of other concepts in chemistry (are some problems about ions a result of carrying Daltonian and Newtonian models of atoms beyond their utility - since in those models atoms are unbreakable; are covalent bonding ideas served at all well by the Bohr model of the atom?) may be a valuable area for research.

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HOW SOLID IS A SOLID: DOES IT MATTER?

Brian Jones

INTRODUCTION

Children's meanings for words used in science and their explanations of why things of the world behave as they do have been the subject of considerable research effort in recent years. Reviews of this work include those of Driver and Easley, 1978; Driver and Erickson, 1983 and Gilbert and Watts, 1983. It is not for their intrinsic interest alone that these studies proceed and continue to receive attention from a widening audience. Some of the impetus for further work stems from a belief that a knowledge of students' conceptual frameworks is very valuable, if not a prerequisite, for planning effective teaching (whether this be judged in terms of the extent to which children understand and use current scientists' frameworks or the degree of refinement of their existing frameworks towards a more fruitful explanation of past experience as well as that acquired through teaching).

In summarizing the argument to justify research programs in this field, Driver and Erickson (1983, p.39) have listed the premise that -

> Well-planned instruction employing teaching strategies which take account of student frameworks will result in the development of frameworks that conform more closely to school science.

The Teachers as Researchers in Primary Science (T.R.I.P.S.) Project was initiated in the latter half of 1983 at the Centre for Education, University of Tasmania on the basis of such a premise. The project is concerned with the teaching and learning of science at primary level, Grades 1-6. It aims to encourage classroom teachers to practise a type of clinical method with the individuals and groups they teach in order to diagnose both the range of children's meanings for words they use in describing the physical world and the alternative frameworks by which children give meaning to their experience. The insights gained will guide the choice of a starting point for teaching various topics and provide a rationale for choosing further experiences to be incorporated into units of work. In this regard Erickson (1983) has expressed concern that students might become locked into a particular pattern of remedial teaching should an existing commonsense framework be viewed like a disease needing treatment by the application of some single best teaching strategy. Thus he prefers to seek to inform teachers of the existence of commonsense knowledge and to

illustrate a variety of ways of getting children to reveal it so that teachers can work with these ideas toward achieving the selected aims of a teaching unit.

Although we do not believe there is a single best way of teaching a topic when the nature and range of the children's prior knowledge is known, we do believe teachers will find it helpful to have, (for particular themes) a documentation of the range of ways some children have used words and viewed phenomena across grades, some suggested experiences worth giving to or discussing with their children to probe understanding and finally suggestions as to what further activities and phenomena children might be exposed so as to broaden their fund of experience of the world and be assisted to adopt more refined and powerful interpretive frameworks.

The T.R.I.P.S. Project intends to produce such background documents for a number of science themes. Since 'matter' and the various phenomena associated with its changes of form are part of the everyday experience of children the science theme 'Forms of Matter' was selected as the first theme to investigate.

Osborne and Cosgrove (1983) have reported aspects of children's views about the processes by which water changes from one state to another. They interviewed children from 8 to 17 years of age; and their reported data showing the extent of different views across ages is confined to Forms 2 to 7.

They found that children associated correct technical terms with phenomena such as condensation, evaporation and melting but further questioning revealed that the concepts underlying these labels were not those commonly accepted by scientists.

The study being reported here differs in two respects. Firstly, it focussed upon children of primary school age, 7 to 12 years (Grade 1-6) and secondly, it used a wider range of common substances to probe children's knowledge of the forms (states) in which substances exist as well as the processes of change from one form to another.

METHOD OF DATA COLLECTION

In order to obtain a wide selection from the total set of children's views and descriptions of matter and its behaviour individual interviews were planned with a group of children from three ability groups within three composite grade levels (see Table 1). Teachers who were undertaking the interviews were asked to select children from their grade according to their judgement of general ability described

by the three categories high, average, and low ability. Two interviews in each of the nine age-ability groups were planned making 18 in all from a small number of schools in different areas of Hobart.

Interviews were to be recorded on audiotape and transcribed for analysis. Following the identification of a variety of views other methods will be used to survey the extent of some across grade levels in a larger population of primary school children.

TABLE I

Model for sampling children's views using school grade and general ability

	Ability**		
Grade* 1-2	A	B	C
Grade 3-4	A	B	C
Grade 5-6	A	B	C

*Grade 1 children are about seven years of age.

**Ability refers to general ability relative to grade as judged by a child's teacher.
A - high
B - average
C - low

Although a teacher's perception of general ability may be unreliable it is believed that the use of such a crude measure may lead to the identification of some views which otherwise could be missed. The sampling model is viewed solely as a tool to facilitate the assembly of a range of children's views and responses without any intention to relate particular responses to the two variables however defined.

INTERVIEW PROCEDURE

Driver and Erickson (1983) have arranged the various methods which have already been used to probe students' alternative frameworks along a Conceptual-Contextual continuum. At one end are methods in which concepts are presented to individuals for their responses and at the other methods, in which a physical situation is provided and students' behaviours are observed. They suggest that verbal, propositional knowledge frameworks can be inferred from the former methods and knowledge as it is applied in action from the latter and that these frameworks may be significantly different.

BOX 1

T.R.I.P.S. PROJECT
Forms of Matter - Interview About Phenomena (I.A.P. Schedule 1)

KEY: T Teacher Q Question/Request

1. LINE UP CUBES ON TABLE
(wood, ice, lead solder, steel, wax, sugar, plasticine)

T I have some different substances here:

Q. 1 Do you know the names of any of them?
Supply name card for those recognized. Check substance by substance.
Finally, provide card for all cubes.

Q. 2 Tell me what you know about this substance: steel.
Clarify verbal meanings of concept words raised - solid, hard, soft, strong, etc. 'What do you mean by ...'

Q. 3 Tell me about any one of the others now.
Probe responses e.g., Is it the same or different from steel?
How is it different?
If ICE chosen use Q.4 then follow with plasticine; if NOT ice then follow selected cube with ICE Q.4.

Q. 4 Tell me about the ice.
What is this substance called? (point to liquid)
Clarify melting, water, etc. if raised.
Is water the same substance as ice? How is water different from ice?
Can we get our ice cube back again? How?
Would this ice be the same substance as water?

Q. 5 Tell me about this substance: plasticine.

Q. 6 You saw what happened to the ice. Can this happen to any of the other substances? Which?
Do we have to do anything to make it happen?
If it happens, is it the same substance or is it a new substance?
Would the substance change back to the way it was before? Why?
When it does change back would it be the same substance as the 'runny' form?

Q. 7 Which of these substances will NOT change like the ice did?
Why do you think that? What might happen to them?

Q. 8 If you heated the water from the ice cube would it change again? Tell me about that.
Clarify, boil, dry up, steam, etc. if raised. Where does the water go to?
How many different forms can ice change into?

Q. 9 How many different forms can wax have?
(What about lead solder? steel? plasticine? sugar? wood?)

Q.10 What do YOU call these different forms substances can be in?

Q.11 Do you know what scientists call these forms?

2. SET UP CANDLE TO HEAT SUBSTANCES IN SPOONS

T I am now going to heat these substances over a candle flame.

Q. 1 Tell me what will happen to the sugar.
(Briefly obtain a response for lead, wax, steel, wood, plasticine.)

Q. 2 What is happening? Tell me about that.
What is this? Point to brown liquid.

T I shall pour some onto the mat.
What is happening now? Is this what we started with?
Repeat Q.1, Q.2, T, for lead.

Q. 3 When lead changes is it as hot as the sugar when sugar changes?

Q. 4 Can I make the lead hotter than it is when just changing? How much? or explain that.

Q. 5 How hot is the lead when it's turning hard again?
Is it hotter, same or cooler than when it turned soft?
Repeat Q.1, Q.2, T, Q.3, Q.4, Q.5 for plasticine, steel, wood.

The method of data collection in this study falls towards the right of centre in such a continuum. By means of clinical interviews children were asked to name and talk about seven samples of matter presented to them and about their behaviour under changed circumstances such as heating them in a spoon over a candle flame. That is, immediate concrete experiences were provided to stimulate children's responses. This was judged to be necessary with younger children in order to reduce the possibility of misinterpreting their cognitive frameworks. As the intention was to explore the way children use words to describe and explain phenomena about matter their meanings of the concept labels they introduced into the conversation were probed with constant reference to the phenomena at hand. When significant words common to the scientist's language about the topic were not introduced the interviewer raised these in the dialogue after a reasonable time. Thus a composite of contextual and conceptual frames was used as in the Interview-about-Events technique (Osborne 1980).

The teacher-interviewers were provided with a schedule of questions and steps by which to encourage conversation and to probe the meaning of language used to describe phenomena presented to them (see Box 1). They were asked to provide as few seeding ideas and terms as possible while maintaining a fruitful dialogue and to view the schedule as a set of starting points from which to diverge according to the unique responses of children. The first part of each interview is concerned with the seven cubes of substances as they are and what might happen to them under different circumstances. In the second part they are heated in a spoon over a candle flame.

SOME RESULTS FROM TWO INTERVIEWS

The analysis of a number of interviews is in progress but for the purposes of this paper only two will be reported here.

Yvonne and Ben are both in Grade 3 (9 years old) and were grouped on ability as type A and C respectively. Both used the words solid and liquid although Ben used solid only after prompting and Yvonne used the word much later in the conversation preferring rather to talk of substances being 'set'. Neither child volunteered the term gas. From their responses it can be inferred that they use the word solid in a different way from the chemist as illustrated in these extracts.

BEN

T Well have you heard of the word solid?
B Yes, or hard. It's very hard.
T Now is solid and hard the same to you?
B Not actually. Cos solid can be all hard inside and other things can be hard but it's hollow inside.
T Which of these seven specimens are solid to you?
B Steel - You can melt the wax but it's not solid.
T Is that piece of wax not solid?
B Oh yeah. It's solid.

T Why do you say it's solid?
B Cos it's not hollow.
T Do you know any substances that are not solids?
B A car is not solid. The bottom of a boat is not solid. It's hollow.

YVONNE
T How many forms can wax have?
Y Two - solid and melted.
T Tell me about solid, you haven't mentioned that word before.
Y When it's not melted - [ice, steel, wax, and lead identified as solid]. Plasticine wouldn't be solid because you can bend it, it would break.
T So you can't break solids?
Y You can break them with a lot of pulling and tugging. The steel, lead, wax and wood would be solid. This [sugar cube] wouldn't because it can go into grains - if you had a grain of sugar it would be solid. In some cases wood cannot be a solid, if you have a chip of wood it's not solid. (because you can break it)
T What about a piece of wire, would you call it solid?
Y No. (because you can bend it)
T What about plastic foam?
Y No, because it can bend.

The concept labels essential to the description of matter by these two children are HARD and SOFT - terms which relate to direct tactile sensing. Hard means difficult to break, distort or bend as distinct from soft which describes things which can be broken easily, squashed or deformed in the hand. Solid is a subcategory of hard and, things so described have a continuity of substance throughout as distinct from things which have a hollow space inside (Fig. 1). Thus the word solid is being used as an adjective to describe the extent of the hard substance in an object. It was not used as a noun to name a class of substances with a certain set of properties as is the case in science.

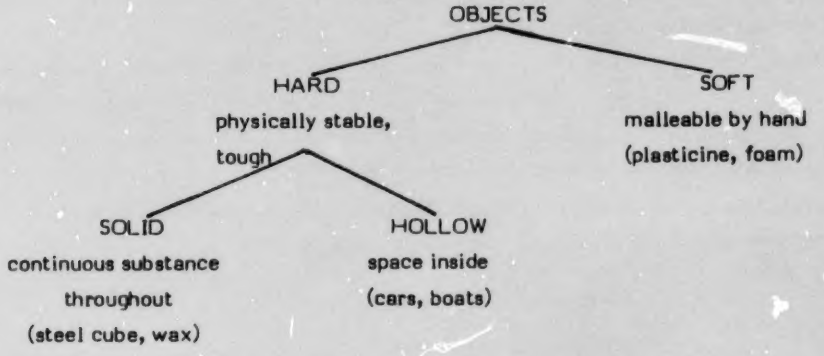

FIGURE 1
A hierarchy of concept labels in Yvonne and Ben's vocabulary

The term liquid was used voluntarily by both children early in their interviews and their concepts, although different from each other, are adequate to classify correctly the common liquids presented to them. A liquid was described by Ben as 'all runny, kinda like a drink - like orange juice' and by Yvonne as 'like water', 'anything melted up' or something 'runny' even if not melted from a solid form. Consider Yvonne's comments:

Y Liquid can mean anything. It can mean skin melted up if it turned into a liquid, but I don't think it would - it would turn into a liquid like a runny fluid.

T What is a fluid?

Y A liquid that's runny.

T Well, are all liquids runny?

Y Yes, unless they are liquids that have been set again.

Here fluid and liquid are used synonymously since she is unlikely to be aware of the flowing properties of gases and solids.

When all of the five liquids produced over the candle flame were tipped from the spoon Yvonne was happy to refer to the flowing action as 'pouring' yet in the case of Ben pourability is not a property of all liquids. Molten sugar and plasticine (and honey) are liquids which do not pour since their flow is not fast enough in his opinion.

B ... but [molten sugar] isn't actually pouring because pouring comes out fast.

T So what do you call tipping it out?

B I suppose dripping - pouring is really fast like pouring water.

For both children the changes of state were associated with heating and cooling but in contrast to the conclusion reported by Schollum et al. there was evidence that the children were aware that different substances melt at different temperatures. In the case of Ben the harder the substance the higher is its melting point. For example consider the following extracts:

T So you think we could melt the steel on this candle?

B No, it needs to be much hotter.

T Do ... things melt at different amounts of heat?

B It depends on what it is.

T Should lead melt at a temperature higher - or lower than wax?

B Higher - cos it's much harder than wax.

T If I got another piece of lead would it melt at the same temperature?

B Yes.

The concepts of heat and temperature were not probed in these interviews but from other responses it was evident that there was confusion between them. Yvonne believed that steel would melt over the candle after about an hour suggesting that it is the duration of heating time which governs the final temperature not some property of the flame.

The melting dissolving confusion was also apparent as Ben considered that dissolving sugar was a special case of melting requiring the addition of water. However he also referred to the disappearance of things when they evaporate as 'dissolving', e.g., the continued heating of wax causes the liquid to 'slowly dissolve ... go into the air and disappear' by which he implied, 'out of sight out of existence'.

The reversal of the melting process was referred to as 'setting', 'drying up' and 'going hard'.

B When [steel] cools down it goes hard.
T If you didn't cool it at all would it stay melted?
B No, but it would take longer to dry.
It, [solder] dries when you blow on it.
T Why do you use the word drying?
B Cos it's turning into a harder substance - I just call it drying.
T Now what will happen to that molten wax in the spoon?
B It will dry up to be wax again - turn into its normal form.
T Does something have to go into or come out of the wax to dry?
B No [implied]. It must cool.
T Is that the only thing we have to do to make it a solid again?
B Yes.

In ordinary speech the concept of drying involves the evaporation of a liquid substance which has wet a surface by spreading over and adhering to it. Because of the semantic association between the words wet, dry, liquid, and solid it is understandable, although confusing, when the word drying is used by Ben to refer to the solidification process.

DISCUSSION AND CONCLUSION

Turning now to the title of this paper one may state, in the language of science, that a substance does not have to be hard or very rigid to be a solid. We commonly speak of soft solids and readily include plasticine, chocolate, plastic foam, and wire in that class of substances which also includes rock and steel. Yet the word solid is used in everyday language in at least two different senses. We talk about 'solid blackwood' furniture and 'solid brick' houses and in this sense we mean there is no

change of the named substance throughout. The wood is continuously blackwood in every direction and the house walls are continuously masonry from outside to inside-face apart from the usual air cavity. In another sense we speak of a person having a 'solid build' and of foundations being 'solid as rock'. Here we refer to the ability of the object to withstand physical distortion or disintegration; things are stiff, unbendable or strong as distinct from weak or crumbly. The two children used the word in these senses.

The first meaning of solid has no similarity to that of the scientist whereas the second has some elements in common. The chemists' solids normally retain their shape without any observable distortion due to the effects of their own weight yet a solid which has crumbled is still a solid albeit in smaller visible pieces. Plasticine although malleable is a solid in the same sense provided the lump is not too large or too warm and is well supported otherwise it will flow under its own weight and may spread even to fill a container in which it is placed.

But the need to use words like 'normally' and 'provided that' alert the reader to the problems inherent in applying the school science schema with its three states of matter which are really not clear cut when it comes to labelling some substances, particularly those outside certain size ranges, time frames, and Earth-bound contexts. A large slab of solid rock for example will flow under the sustained force of its own weight and after some time may produce a contorted shape. We get over this anomaly by saying that solids can behave like liquids or we introduce the word fluid to describe the behaviour of the solid under special conditions. Considering another case a globule of water in free fall in a space craft is unlikely to satisfy one of the usual properties of a liquid namely, taking the shape of a container in which it is placed.

'Does it matter?' This discussion has only hinted at the difficulties which teachers must face when teaching and applying the scientists' language about forms of matter. What also matters is that children in our primary schools are using some of the scientific words in a variety of ways. If teachers are to refine and extend the children's use of this vocabulary they will need to be alerted to current variants of meaning so as to be able to give attention to the selection of experiences of matter which will provide a context for fruitful dialogue between children and between teacher and children. Ultimately children's understanding of matter will also be changed.

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Research in Science Education, 1984, 14, 114-124

PUPILS' IDEAS ABOUT FLOATING AND SINKING

Fred Biddulph and Roger Osborne

INTRODUCTION

With the removal of Archimedes' Principle from many Physics syllabuses there has been a tendency to ignore floating and sinking as a topic of value at all levels of the school science curriculum. However the importance of understanding some elementary ideas about floating and sinking is difficult to challenge for water-sports minded Australasians. Moreover we would argue that there are many elemetnary ideas about floating and sinking (excluding advanced ideas like displacement and Archimedes' Principle) which help children begin to develop, informally, important scientific concepts such as the relationship between weight and volume.

The above ideas, among others, led the Learning in Science Project (Primary) team to propose that floating and sinking would be a viable topic for primary school science (Harlen & Osborne, 1983). Although some studies of children's ideas about floating and sinking have already been made (Inhelder & Piaget, 1958; Laurendau & Pinard - cited by Good, 1977; Rowell & Dawson, 1977; von pfuhl Rodrigues, 1980) it was considered desirable to carry out a much broader investigation of children's ideas on the topic as an essential precursor to the development of teacher guide material. A comprehensive investigation was therefore undertaken to identify the meanings and ideas that 7-14 year old pupils tend to have about floating and sinking (Biddulph, 1983). This paper presents some of the major findings of that investigation.

THE INVESTIGATION

A total of 144 pupils aged 7-14 years, representing a range of ability at most age levels, were interviewed individually. Four interview schedules were used but constraints relating to pupil availability meant that not all pupils were interviewed on the whole four schedules. Briefly, the interview schedules comprised:

- a probe of children's meanings for 'floating' using 15 cards depicting instances and non-instances of 'floating' (see Appendix 1);
- an exploration of children's explanations for why things float or sink using 10 homogeneous materials, some of which floated (e.g., piece of candle) and some of which sank (e.g., metal paper clip) (see Appendix 2);

- an investigation of whether or not children thought length of an object or depth of water affect flotation, using materials and objects in water: (e.g., floating a shorter and longer piece of candle in water);
- a check on pupils' ability to understand that an object made of non-floating material displaces more water when floating than when sunken: (e.g., plasticine shaped to form a boat).

The interviews were audio-taped and later transcribed.

Surveys

A survey schedule was developed as a means of exploring the prevalence of ideas which emerged during the interview phase. Three classes of average or mixed-ability pupils at each level from 8-12 years (429 in all) were surveyed to find their meanings for 'floating' and their ideas of whether or not the length of an object or the depth of water affect flotation level. The cards and materials used are exemplified in Appendix 3.

CHILDREN'S MEANINGS FOR THE TERM 'FLOATING'

There are at least three distinct situations where an object would be considered floating in the scientifically accepted use of the word.

> An object or material may be considered to be floating in water if it is at the surface and partly immersed (e.g., a ship), if it is on top of the surface and is supported by the surface tension (e.g., a spider) or if it is entirely submerged but freely suspended (e.g., a fish).

Let us now consider children's ideas.

Objects at the surface and partly submerged

Most children thought that objects in this position were floating if a sizeable proportion was above the surface. For example, with respect to the card depicting a person wearing a life jacket, all 104 pupils interviewed considered the person to be floating.

> [Person in life jacket] It's floating because he's on the surface of the water. It's just some parts of the body that are under. (13 year old)

When only a minor portion of an object was above the surface, however, some pupils took a different view. They said that part of the object was floating and part was not. Of the 104 children interviewed, 19 spontaneously used this type of categorisation on 23 occasions. For example, a 14 year old said of the beer bottle,

> Some of it's floating and some isn't. The top part is.

A 9 year old commented on the iceberg in a similar way,

> It's floating and not floating. The top is floating and the bottom's not.

When 76 pupils were asked what would happen if the top was cut off, 37 of them (48%) said the bottom part would sink.

A survey question was used to determine the likely prevalence of the view that an object could be partly floating and partly sinking. Pupils were asked if in their view the floating bottle (Appendix 1. No.6) was 'floating', 'not floating', 'partly floating and partly sinking', or if they were 'not sure'. Of the 426 children who responded to this item, 178 (42%) chose the part floating/part sinking category, although this particular result needs to be viewed with some caution.*

Dynamic considerations influenced children's decisions about some objects at the surface and partly immersed. Perceived downward or horizontal movement resulted in some children saying that an object in this position was not floating. For example, 54 of 104 pupils said that the yacht was not floating. Typical responses were,

> It's getting fuller and it's sinking. (8 year old)
>
> It's gonna go down to the bottom. (14 year old)

Sixteen of the same 104 pupils considered the speedboat to be not floating because it was moving along. For instance,

> It's going fast, and floating is staying still and just floating around. (8 year old)

Objects which appear to be on top of the water

Some pupils considered that objects in this position were not floating. For example 33 of the 104 students (but none of the 20 children at the 7-8 year level) who looked at the card depicting a spider standing on the surface of the water considered that the spider was not floating. The most common reason given was that it was entirely on top of the water; for example, being held up by the water's 'skin'. This is illustrated by an 11 year old pupil who said

> It's standing on the s... there's a layer of water or something, they don't disturb it. It's like putting a pin on a piece of tissue and getting it to float.

---

*In considering the implications of the above result it should be kept in mind that in real life situations the amount of a floating object which is beneath the surface tends not to be noticed. Our classroom observations tend to suggest that the prevalence of the 'part floating' and 'part-not-floating' views mentioned above is exacerbated by the observation of cross-sectional drawings.

In the sense that the floating is a result of surface tension being a significant factor, it is useful for pupils to distinguish these cases from situations where surface tension has no significant effect.

Objects completely submerged but freely suspended

Some pupils also considered that objects in this position were not floating. For example, 36 of the 104 pupils who were interviewed using the cards said that the person snorkelling under water was not floating. Reasons included,

He's under the water. (10 year old)

That's just totally submerged under the water. (13 year old)

To establish the prevalence of this view, pupils were shown the submarine (Appendix 1, No.9) and asked if they considered it to be 'floating', 'not floating' or 'not sure'. Of the 419 children who responded to this item, 183 (44%) chose 'not floating'.

Summary

Children's meanings for flotation with respect to objects partly immersed in water were largely compatible with scientist's views. This type of object was the focus of the remainder of the study but in the subsequent interviews and surveys it was made clear to pupils, when necessary, that an object would be considered floating if it did not go to the bottom.

PUPILS' EXPLANATIONS OF WHY THINGS FLOAT

An object will float if it has sufficient volume to displace an amount of water equal to its own weight. We will compare this idea with children's explanations.

One hundred and three children were interviewed on the second schedule (see Appendix 2) after they had experimented with the materials in the water. They were asked if there was one reason why some of the things floated.

Only 35 pupils could offer a single reason. Of the reasons offered, the one most frequently given was that things float because they are light (21 of the 35 pupils gave this reason). It was given more often by the 7-10 year old children and is illustrated by a 10 year old who said that things float,

Because they're kind of light.

Only three of the 21 children who gave 'lightness' as an explanation (one each at the 10, 11, and 12 year old levels) qualified it by saying that certain things floated because they were light for their size. The rest had an absolute notion of lightness.

With the exception of these three pupils, and one 14 year old who made a reasonable attempt to explain flotation in terms of density, no others offered an explanation that could account for flotation generally. This result is consistent with a finding of Rowell and Dawson (1977) when they pretested 61 pupils aged approximately 14 years.

Seventeen pupils, all 11-14 year olds, seemed to be aware that there could be a single reason or rule but they could not state it. Many pupils hesitated then said that they did not know, as the comment of the following student shows,

> ... ah, there probably is one reason why they floated, but I don't know what it is. (12 year old)

The remaining pupils 51 of the 103) each offered more than one reason. In fact 17 of the 30 at the 9-12 year old levels, despite being specifically asked if there was one reason why some of the things floated and some did not, promptly returned to giving reasons for individual objects. The impression gained during the interviews was that these pupils could not really conceive that a single explanation was possible.

In all cases where pupils did offer specific explanations for particular objects there seemed to be little difference in reasoning with age. For example 7, 9, 11, and 13 year old pupils gave similar reasons for why the pumice floated.

> It's got lots of holes, lets air inside it and that keeps it from going down. (7 year old)
>
> Because pumice is, even though it feels heavy it's got holes through it and the holes suck in air that keeps it afloat'. (9 year old)
>
> Probably 'cause it's got those little holes in it which carries air and all that in. (13 year old)

PUPILS' VIEWS OF WHETHER LENGTH OF MATERIAL AFFECTS THE LEVEL AT WHICH IT FLOATS

Different lengths of candle were used to probe children's ideas about the level at which they thought a long piece of material would float compared with a shorter piece of the same material which they saw floating. The 80 children made a variety of predictions about the outcome of altering the length of the candle. Some 20% of pupils interviewed predicted that the longer candle would float at the same level as the shorter one, which it does. For example,

> It would float about the same level. It's like a log. It's just the same as that wee candle, just like if you had cut it up. (11 year old)

Over 30% of the children considered that the longer candle would float at a lower level, for example,

It will float a little bit lower because it's heavier. (12 year old)

About 25% of the children thought that the longer candle would sink. Typical predictions were:

It'll sink. It's longer and it's more heavier. (9 year old)

It'll sink because it's heavier than the lighter candle. (13 year old)

To investigate the prevalence of the various ideas that children hold regarding length of material and flotation level, 8-12 year old pupils were surveyed with the same materials (candles) and approach used in the interviews. The survey results are shown in Figure 1.

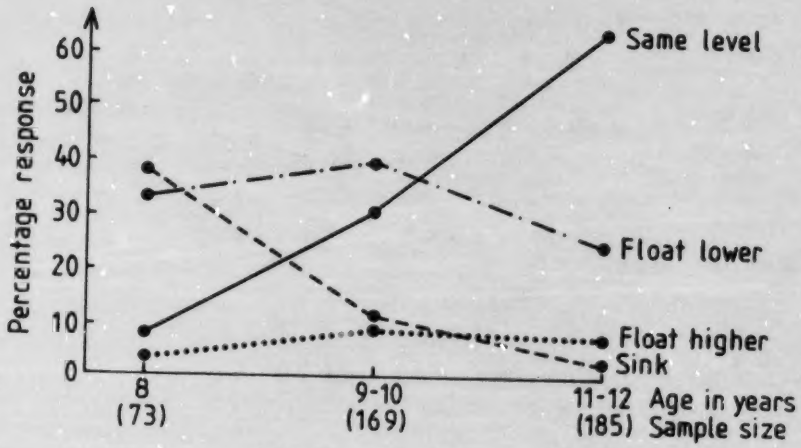

FIGURE 1

Pupils' predictions about the flotation level of a full length candle compared with a short piece of candle.

The survey clearly shows that as the children got older an increasing percentage considered the longer candle would float at the same level as the smaller candle and that a decreasing percentage considered the longer candle would sink or float lower. However, there was still a sizeable proportion of older children who thought length would affect flotation.

PUPILS' VIEWS ABOUT WHETHER DEPTH OF WATER AFFECTS THE LEVEL AT WHICH AN OBJECT FLOATS

The depth of water which may be thought to affect the flotation of an object can be underneath the object or on top of it. To investigate the first case the children who were interviewed were shown a plastic boat floating in a bowl of water. They noted which mark on the side of the boat the water level was at and were asked to predict which mark it would be at if the boat were floating in a deep lake.

More than half the pupils interviewed predicted that the boat would float at the same level, which is the scientifically accepted view. A typical comment was,

> The water's still, I mean the boat is still the same weight. I mean it's not going to be put down any further; it doesn't matter how deep the water is. (14 year old)

Twenty-five per cent of the children interviewed predicted that the boat would float at a lower level. Reasons given included,

> Because the water is deeper and sort of sucks it down. (9 year old)
>
> It might sort of go down more. It's much deeper and that, much more water. (13 year old)

About 16% of the children interviewed predicted that it would float at a higher level. Examples of their explanations are,

> There is more weight from underneath to hold it up. (8 year old)
>
> Because it's a greater volume of water and it's got more pressure in it to lift it, to hold it up. (12 year old)

The prevalence of these ideas among 8-12 year olds was investigated by survey using a picture depicting a launch setting out from a jetty at the edge of a lake into the deeper water. The children's predictions about the level of flotation of the launch in deeper water compared with the level of flotation in shallower water are shown in Figure 2. The figure shows that by age 9-10 years the majority of children considered that the launch would float at the same level. However, even at the 11-12 year old level there were some children who predicted that it would float at a different level.

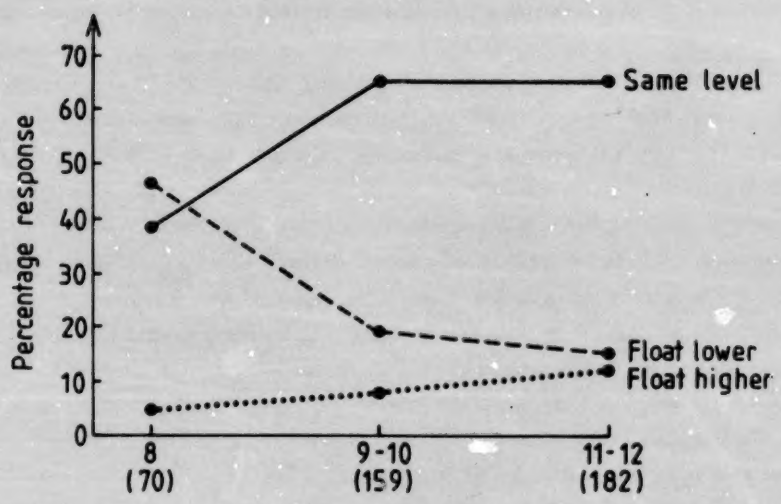

FIGURE 2

Pupils' predictions about the level of flotation of a launch in deeper water.

PUPILS' VIEWS ABOUT DISPLACEMENT

Our view has been that if children begin to grapple with the idea that things that are 'heavy for their size' tend to sink while things that are 'light for their size' tend to float, then that would be sufficient and useful at the primary level. Nevertheless we were interested to know if children aged 7-14 years understood

- that a material such as plasticine will displace the same amount of water when immersed, irrespective of shape, and
- that if the material was reshaped so that it floated then it would displace more water when floating than when immersed.

Our investigation showed that only 26 of 80 pupils interviewed correctly predicted that the same amount of water would be displaced, irrespective of shape when an object, such as plasticine, is immersed in water. The typical reason was

Because they're the same amount, just different shapes. (7 year old)

Most of the children predicted that the amount of water displaced would be less (46 pupils) or more (7 pupils).

Eleven of the 80 children interviewed correctly predicted that the plasticine would displace more water when it was reshaped and floating than it did when immersed. This number was more or less evenly spread across the age range. Most pupils predicted that the amount of water that would be displaced would be less (49 children) or the same (19 children). A typical reason for predicting less was,

> ... if it's going to be floating it won't be pushing out the same amount; there'll still be some more [plasticine] above the surface. (14 year old)

Even when the pupils observed that the reshaped plasticine displaced more water when floating than when immersed, many were puzzled by it. Cognitive conflict alone is certainly insufficient to help pupils construct useful views about floating and sinking (see also Rowell & Dawson, 1977).

SUMMARY AND IMPLICATIONS

The interviews revealed that different children attached different meanings to the term 'floating' and that this varied with context. The indications are that there are likely to be children in most classrooms whose meaning for 'floating' conflicts with that of scientists.

The children had a range of views of why some things floated and others sank. In a significant number of cases the younger children (7-10 year olds) did not realise that there could be a single explanation. Their response was to begin giving explanations for individual materials. The explanations offered, whether multiple or single, could be described as partial explanations. They focussed on specific aspects such as lightness or heaviness and failed to take into account other aspects (such as size) needed to formulate a general rule that would explain all cases. Some students, especially 11-14 year olds, realised that they did not really have a simple single rule for why things floated, but they appeared interested to learn of such a rule.

A number of children had the idea that the length of floating material, or the depth of water underneath affected flotation level. Only a minority of pupils were able to make correct predictions about the amount of water non-floating material would displace when either differently shaped or when floating. Nevertheless, almost without exception the pupils said that they enjoyed working with and thinking about the various materials. Their ideas and positive feelings toward 'floating and sinking' suggest that it is a topic with potential; there are many simple ideas about flotation that can be developed at the primary level which are useful in their own right, as well as being helpful for further learning in science and mathematics. The findings have therefore been used to develop resource booklets for teachers. These incorporate

both the ideas children are likely to hold and suggestions for investigations and other means to challenge children to change, modify or extend their ideas (see for example, Biddulph, Freyberg, and Osborne, 1983).

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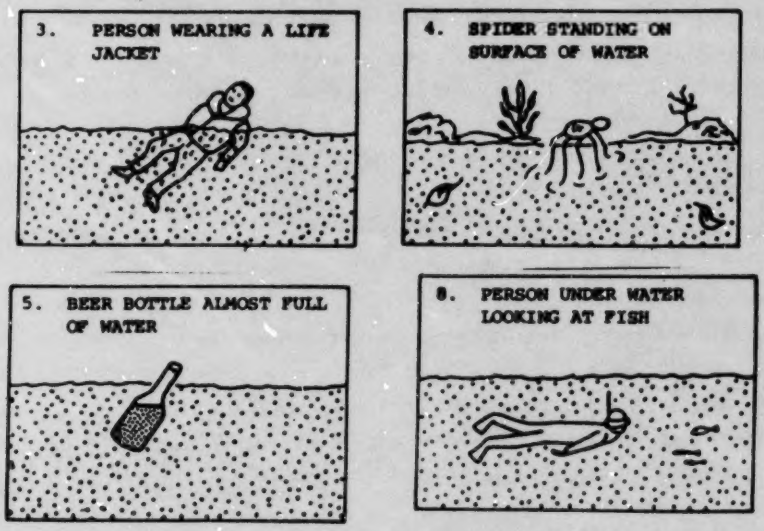
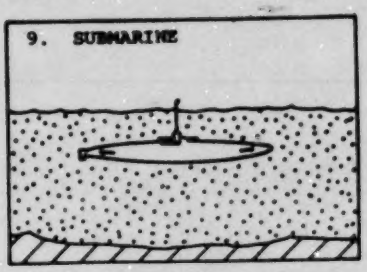
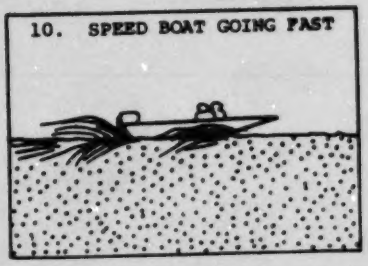
APPENDIX I

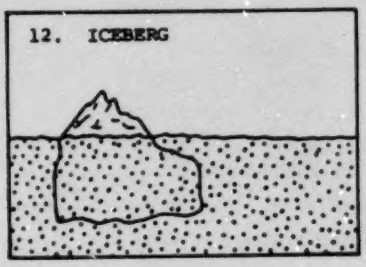
Examples of the instances and non-instances of 'floating'

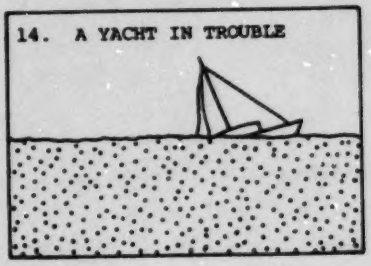

3. PERSON WEARING A LIFE JACKET
4. SPIDER STANDING ON SURFACE OF WATER
5. BEER BOTTLE ALMOST FULL OF WATER
8. PERSON UNDER WATER LOOKING AT FISH

Appendix I contd









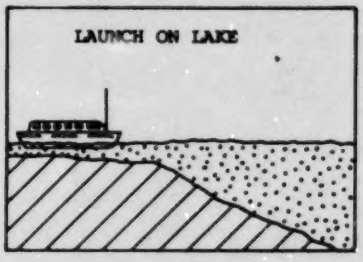
APPENDIX 2

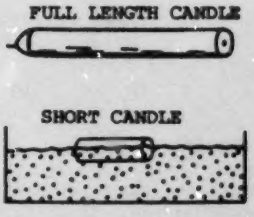
Materials used in second interview schedule

Small, rectangular wood block (approximately 60 mm x 40 mm x 20 mm); metal paper clip; school rubber (eraser); oval piece of pumice (approximately 70mm x 50 mm); short length of candle (approximately 65 mm); small block of aluminium (approximately 25 mm x 25 mm x 10 mm); flat piece of thin polystyrene (approximately 75 mm x 55 mm); flat piece of thin fibreglass (approximately 115 mm x 75 mm); small piece of white chalk resembling pebble (approximately 10 mm long); small, solid plasticine ball (approximately 20 mm diameter); bowl of water to test the materials in.

APPENDIX 3

Additional card and materials used for survey (each card was A4 size)





Research in Science Education, 1984, 14, 125-136

CIRCULAR MOTION: SOME PRE-INSTRUCTION ALTERNATIVE FRAMEWORKS

Richard Gunstone

INTRODUCTION

The widespread existence among students of alternative frameworks or naive theories in the area of mechanics is now unquestioned. (For reviews of relevant research written from a number of different perspectives see Champagne, Klopfer & Gunstone, 1981; Driver & Erickson, 1983; Gilbert & Watts, 1983; Osborne & Wittrock, 1983.) Our interest in the specific area of circular motion was sparked by a paper by Gardner (1981) and subsequent reaction by Deakin and Troup (1982). Some previous work has been done in this area. As a consequence, it was decided to design and use a pencil-and-paper test rather than to interview.

THE DEVELOPMENT OF THE TEST

An analysis of the literature suggested three significant ideas of relevance to an exploration of children's explanatory frameworks for circular motions. The first, not specific to circular motions, was the belief that motion implies force (Osborne, 1980; Watts, 1983); the second was of an impetus theory perspective (McCloskey, Caramazza, & Green, 1980); the third was a belief in centrifugal force (Viennot, 1979; Warren, 1979). The test was designed to explore the existence of each of these three perspectives. In addition, beliefs about the static case (usually seen as an antecedent to linear and rotational dynamics in physics courses) were also explored. Situations which were likely to be seen as everyday, real, and more readily identified with the study of physics were included.

Box 1 gives an outline of the nature of each question; two questions are shown in Boxes 2 and 3.

BOX 1

An Outline of the Contents of the Test

Introduction: A brief explanation of the use of arrows to represent forces.

A shoe polish tin on a table

Qs 1-2	Tin is still. Q 1: Show all forces acting on the tin. Q 2: Total force on tin is 'A. zero, B. not zero', explain the answer.
Q 3	Total effect of unequal, opposite forces on the tin.
Qs 4 & 5	Tin is sliding at constant speed on a smooth table. Q 4: Show all forces acting on the tin. Q 5: Total force on tin is 'A. zero, B. not zero, and in the direction of motion, C. not zero, and in some other direction', explain the answer.

A car is driving at constant speed on a straight road

Qs 6 & 7	As for Qs 4 and 5.

Shoe polish tin connected by a string to a peg in the centre of a smooth table

Qs 8 & 9	Tin is still, as for Qs 1 and 2.
Qs 10-13	Tin is set moving by a tangential push. Q 10: Description of tin's speed during the push. Q 11: Description of tin's speed after the push. Qs 12 & 13: After the push, as for Qs 4 & 5.

A moon of Jupiter travelling at constant speed in a circle around Jupiter

Qs 14 & 15	Q 14: Are any forces acting on the moon? Q 15: As for Q 5.

Balls rolled into curved pipes on a table top

Qs 16 & 17	Draw path of ball on leaving pipe and explain. Q 16: Pipe curve 90°. Q 17: Pipe curve 250°.

An argument which 'explains' satellite motion by 'justifying' centrifugal force

Q 18	Parts (i)-(v), representing the five parts of the argument. For each, 'explain why you agree or disagree'.

A ball hangs from a rubber band and is level with a table top

Qs 19 & 20	Ball is still, as for Qs 1 & 2.
Qs 21 & 22	Ball pulled down 5 cm and released. Q 21: When it is level with the table top, as for Q 5. Q 22: When ball is at its highest point, as for Q 2.
Q 23	Ball is pulled down more than 5 cm and released. When level with table top, compare force with that in situation in Q 21.

A car travelling at a steady speed on a flat circular road

Qs 24 & 25	Forces on the car, as for Qs 4 & 5.

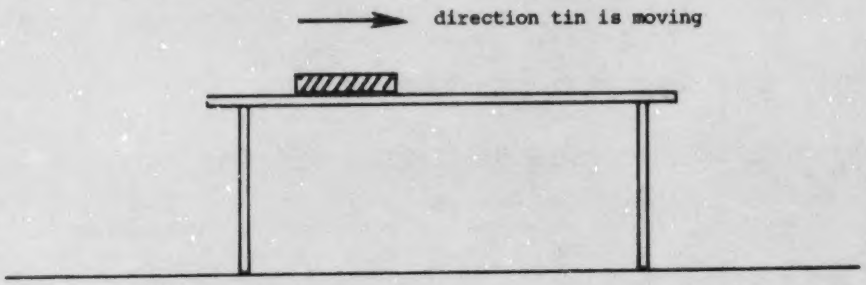
'You' are in the back seat of this car, which is open

Qs 26 & 27	Forces on you, as for Qs 4 & 5.

BOX 2

Questions 4 and 5 from the test (answer spaces not included)

A tin is sliding at a constant speed on a smooth table.



4 On the diagram, draw arrows to represent the forces acting on the tin. Label the arrows with words describing what causes the forces.

5 The total force on the tin is

A zero

B not zero, and in the direction of motion

C not zero, and in some other direction.

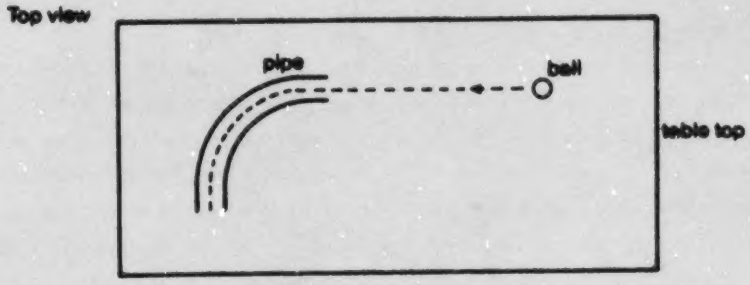
(Circle your answer.)

Explain your answer to question 5.

BOX 3

Question 16 from the test (answer spaces not included)

16 Imagine that we roll a ball along a table so that it goes into and through a curved pipe.



On the diagram, draw the path the ball takes after it comes out of the pipe.

Explain your answer.

THE SAMPLE

The test was administered to a sample of Year 10 students in a Catholic girls' school (the one used by Gardner, 1984) and in a state high school. A total of 68 students participated: one gave no answers to any questions (see postscript). Included in the 67 respondents were 10 from one class who had completed a non-traditional unit on aspects of forces and motion. (This unit used teaching ideas for normal reaction by Minstrell (1982), and some of the approaches used by Champagne, Gunstone, and Klopfer (1983) in their study to change children's world views about force and linear motion.) The other 57 had not had an equivalent experience, although those from the Catholic school had been briefly exposured to traditional approaches in introductory mechanics.

Ten students who had experienced the non-traditional unit in introductory mechanics are included in the general discussion below.

RESULTS

A few students found the test difficult or repetitive to the point of frustration. Thirteen students (19%) failed to answer Qs 26 and 27; occasionally 'I don't know!' was written for some later questions. Question 18, which asked for opinions about the five points in a centrifugal force justification, was the question for which this frustration was most evident. Despite this, a number of expected and unexpected issues emerged. These are discussed below.

Motion Implies Force

This view was widespread and pervasive. Through diagram or statement, 56 respondents (84%) indicated a force in the direction of a constant speed motion. Of the remaining 11, 9 gave ambiguous answers which might have indicated a force in the direction of motion. The 'motion force' carried a variety of names when it appeared on diagrams: push, momentum, energy, movement, friction, gravity (two students indicated gravity was almost horizontal), velocity, petrol, lightness of object. Some of this terminology suggests that 'motion implies force' may not be the underlying logic. However statements show that this suggestion is unreasonable for many students. For example, for

> Q 7 (total force on car): 'If it was zero the car wouldn't move, if it was in some other direction it would move in that direction': 'Not zero because force is needed to travel in the direction of motion'.

and

> Q 14 (Jupiter's moon): 'There has to be a force to have movement'.

Perhaps the most powerful demonstration of this belief arose, quite unexpectedly, in Q 18. Point (v) of the argument, to which students were asked to explain their agreement or disagreement, read

> The circular motion causes the centrifugal force. There is no centrifugal force until there is circular motion. Straight-line motions do not create a force, only circular ones do.

Of the 57 who answered this question, 23 expressly disagreed on the grounds that straight line motions create forces also.

Gravity As a Push

In Qs 1 and 2 it was not always clear if gravity was given as a force on the tin. By the most liberal of interpretations 54 students placed a gravitational force on the tin. Of these, 37 indicated a push rather than a pull.

This was surprising. It appeared to be the result of seeing gravity as a force preventing rising. 'Holding down' was a commonly used expression, and 8 students expressly described the floating which would result from the absence of gravity. There is also some indirect evidence that some students equated air pressure with gravity: one student noted that there would be no gravity in the absence of air; another labelled a force 'air pressure (gravity)'.

The Concept of Point Mass

A grasp of this abstract concept was not common. For example, of the 54 students who indicated a gravitational force in Q 1, 23 showed this force by multiple arrows acting on the tin. A further 18 used multiple arrows for some other force, often air pressure.

The multiple arrows were sometimes spread in direction around the body. This is most likely related to 'pushing down' and 'gravity is air pressure' notions described in the previous section.

The Meaning of 'Total Force is Zero'

Question 2 asked 'If we add up all the forces on the tin, the total force is (A) zero, (B) not zero'; explain. Nine students showed a physicist's understanding of the equilibrium condition, and yet answered 'B' (not zero total force). Parts of their explanations indicate why; for example,

> 'If the two forces equalled zero the tin would be floating in air. The forces aren't zero but they are equal because the object is still'.
>
> 'The gravity pushing the tin down is not the same force as the table holding it stable'.
>
> 'If it was zero, there would be no forces'.

The issue here seems to be an amalgam of an absence of a vectorial view and an interpretation of zero as 'nothing at all'. Another seven students answered B after showing on the diagram in Q1 forces which appeared to indicate a physicist's interpretation of equilibrium, but in their explanations they did not address the issue discussed here.

Interpretations of Diagrams

In a number of cases on the test, diagrams were 'scientific' rather than 'real': that is, some presented the minimum information thought to be necessary for unambiguous interpretation, in a somewhat stylized form. For example, Q 16 (see Box 3) did not show a table in perspective; rather, the question relied on a stem and the label 'top view', to carry the message that the pipe was horizontal. Eleven students (16%) did not get the message; they interpreted Q 16 and Q 17 to indicate the pipe as vertical.

Problems with diagram interpretation may have affected responses to Q 8, in which a tin sits stationary on a smooth table, with a string running from the tin to a peg in the centre of the table. The diagram shows the string as a horizontal line. Twenty eight students (42%) indicated that the string exerts a force on the tin, but did not show a friction force. Some may have been led to this conclusion by the misleading (in terms of reality) nature of the diagram.

In retrospect we should not be surprised by the difficulties caused by these diagrams: conventions and assumptions surrounding scientific diagrams are not always clear and logical to learners.

Impetus Perspectives

Questions 16 and 17 (ball rolled into horizontal pipes of 90° and 250° curve) were specifically designed to explore the existence of impetus theories. As suggested above, some students interpreted the diagrams as vertical (11 for Q 16, 10 for Q 17). In addition, six students did not answer the questions, and two answered both questions in terms of the path of the ball inside the pipe. This left 48 students answering Q 16 and 49 answering Q 17 in the manner intended.

For Q 16 a curved path leaving the pipe was drawn or explained by seven students (15% of the 48 answering as intended) and for Q 17 by 23 students (47% of the 49 answering as intended). In addition, two students changed their answers from curved to straight in Q 16 and another two changed answers in the same way for Q 17. Two students gave a 'curved answer' for Q 16 and a 'straight one' for Q 17. Hence 18 students saw the larger bend as producing a curved motion on leaving and the smaller curve as producing linear motion. One of those who interpreted the diagrams as vertical showed an impetus view on Q 16, but other responses from this group were difficult to interpret.

The explanations of curved paths were not surprising. In essence these either involved a 'retention of curved motion' or a 'retention of force causing the curve' perspective, with a few being of the tautological nature which can arise from trying to explain the obvious. For example:

> 'The ball will be used to the circular motion it came out of'. (Q 17)
>
> '... the pipe has forced it to constantly keep on travelling in a circular motion'. (Q 17)
>
> '... there is force on the ball, it takes its route and the force pushes it into an "orbit" until it stops ...'. (Q 17)
>
> 'The ball will go around because centrifical [sic] force was pushing against the pipe'. (Q 17)

'Because the ball continued along a slightly curved line it should continue along this line'. (Q 17, similar for Q 16)

For one student,

'It will go in a straight line when it comes out of the pipe (theoretically)'. (Q 16) (Curved path given for Q 17.)

This student seems to believe that the situation in Q 16 would give a curved path. Of the other 17 answering straight path for Q 16 and curved for Q 17, one took Q 16 as a vertical pipe, four gave no clear reason for their different answers, six attributed the curved path from the larger pipe resulting from the longer curve in this case, and six saw the end of the pipe in Q 16 as being straight - hence giving linear motion. Neither of the two students giving a curved path for Q 16 and a straight path for Q 17 gave any reason for the difference.

Use of the Concept 'Centrifugal Force'

Question 18 (the five-point argument 'explaining' centrifugal force) was included in the test to probe this issue. However this Year 10 sample, as discussed above, found the question complex and frequently concentrated on an unexpected aspect of the last part of the question. Consequently the data from this question were not analyzed from the centrifugal force perspective.

The test contains four circular motion examples for which forces acting were asked: tin on table (Qs 10-13), moon of Jupiter (Qs 14 and 15), car on circular road (Qs 24 and 25), 'you' in the car (Qs 26 and 27). As a first step to exploring the use of the centrifugal force concept in these cases, all responses which used the term centrifugal or which indicated any form of outward radial force were recorded. (Those cases where the outward radial force was one of a number in all directions labelled 'air pressure' were not included.) The resulting count showed 22 students giving one or more such responses. Of these only six used the term 'centrifugal', one used the term 'centrifical' (and used the same term in discussing Q 17, as quoted under Impetus Perspectives above), one described a 'force pushing outwards' in all four cases without using a name for the force, and one a 'force created by the curve' in Q 25 (i.e., after this phrase had been used in the argument presented in Q 18). Of this total of nine students, one used 'centrifugal' on one occasion only and showed it as a force in the direction of motion. Hence it seems reasonable to suggest that only eight of the 67 students (12%) clearly showed a form of centrifugal force concept. Responses from the remainder of the 22 students were: an arrow drawn radially outwards but not labelled - 10 students (and in six of these cases, an unlabelled force was also drawn radially inwards; in some of these cases students may have been showing forces from air pressure); one student drew an outwards radial arrow

labelled 'momentum (not a force)'; one student twice showed an outwards radial arrow and labelled it 'reaction' (Q 10) and 'friction' (Q 24); one drew a force outwards from Jupiter to its moon (Q 14). This low level of use of centrifugal force was surprising. Even more surprising was the failure of Qs 24-27 to elicit responses suggesting some form of personal experience. Only four such responses were found.

> 'If people were in the car would experience a shift to one side. So surely the same force must be present even if people aren't their [sic] to experience it'. (Q 25)
>
> For Q 27, answer B 'because as you turn, gravity + also the speed of the car make you lean towards the inner part of the car'.
>
> 'Direction centrifugal force pushes you + also your reaction by leaning into away from it'. (Q27)
>
> For Q 27, answer B 'because there is a force of gravity "pushing me" down or inwards in the direction of motion'.

The Sample from the 'Non-Traditional' Unit

The teacher of this unit made extensive use of discussion, student interpretations, and debate. In the time available for the unit, the static equilibrium case was developed to the satisfaction of the teacher, but time constraints forced a transmissive summary of the moving equilibrium case rather than a shifting of the class to a Newtonian consensus.

This showed clearly in the data. For these 10 students, gravity was always a pull, normal reaction was used in Qs 1 and 2 in every case (and widely used in an appropriate fashion in other situations), and Q 2 was answered appropriately (given the alternative interpretation of 'total force is zero' discussed above) by nine students.

CONCLUSION

The most significant issue to emerge from these data is the very small extent to which personal experience was elicited by Qs 24-27. There are two obvious possible explanations for this. Either the questions were inappropriate prompts for probing these experiences, or personal experiences are less powerful in forming views about circular motion than is commonly asserted. Support for the latter explanation is provided by the low level of use of a centrifugal force. It may well be that this fictitious force emerges through a combination of experience and being focussed on the issue by studying physics, as centrifugal forces have been more commonly used by students at higher levels of physics (Gardner, 1984; Viennot, 1979). Further work is needed before either of the explanations advanced above could be accepted.

Much of the discussion of data above is self-explanatory in terms of implications for learning and teaching. However one other issue deserves comment.

Impetus-based interpretations of some situations are common. However students using this perspective in the case of the pipes on the table rarely used impetus to explain other circular motions. This is not surprising. Parsimony of explanatory systems is only an issue to those well versed in science views of natural phenomena: children are generally not concerned by such matters.

POSTSCRIPT

Reference was made to a student who gave no answers to any question; she wrote a note about school science which is not relevant to the main thrust of this paper but which has a general message:

'Dear Sir,

I cannot see the worth of this survey. In fact I cannot see the worth of doing science courses at all. Nothing we talk about is used or related in our life. I have never used anything I've learned and never really thought deeply about the "wonders" of science. Accepting things as they are is fine with me. Pulling things apart to see how they work is okay with clocks and radios - not with tiny atoms we can't even see.

What's the use?' [Signed]

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CIRCULAR MOTION: SOME POST-INSTRUCTIONAL ALTERNATIVE FRAMEWORKS

Paul Gardner

INTRODUCTION

Despite the many personal experiences that physics students (and others) have with objects which travel in circular paths, the dynamics of circular motion is arguably one of the most difficult topics in the senior seconary school physics course.

In an earlier paper (Gardner, 1981) the popular but misleading concept of centrifugal force was analysed and the various meanings attached to this term by some teachers, textbooks, and students were discussed. In certain situations - when one describes circular motion from the vantage point of someone within the accelerated frame of reference - the concept has its uses. However, most usages of the term 'centrifugal force' are simply logically incompatible with Newtonian physics.

It is obvious that some people have considerable difficulty with this concept. For example, in a later issue of the same journal that had published a protracted debate on centrifugal force (Gardner, 1981; Deakin & Troup, 1982; Gardner, 1982), we find this misconceived 'explanation':

> How a centrifugal clothes dryer works
>
> Obtain a milk powder can and punch in its sides quite a number of holes with a nail. Punch three holes equi-distant from each other around the top of the can. Suspend with three cords and attach these to the screw eye in the drill chuck. Make a cylinder out of cardboard or find a pail a little deeper than the can (a pneumatic trough will be suitable) and considerably wider. Place a bit of wet cloth in the can attached to the drill. Lower the can into the cylinder or trough and spin it rapidly with the drill. The water is thrown out of the cloth and can by the centrifugal force. (Note 1)

The fact that a science teacher can write such an 'explanation' (and that the editor of a science teachers' journal can accept it for publication) indicates just how deeply entrenched this misconception is.

Several writers have drawn attention to tertiary students' conceptual difficulties in this area of physics. Warren (1979) asked English university entrants to draw an arrow representing the resultant force on a car travelling along a horizontal, circular road at constant speed; 40 per cent drew a resultant forward force while 28 per cent drew a vector representing a centrifugal force. In the U.S. McCloskey, Caramazza and Green (1980) asked freshmen physics students to predict the subsequent path of balls leaving a curved tube, or balls breaking away from a radial string. About a third to a half of the students predicted that the balls would follow a curved path, implying a belief in a kind of conservation of curvilinear motion. In Europe, Viennot (1979) argued that many university students treat circular motion as an example of an equilibrium situation, and this leads them to invent an outward force to counterbalance the inward force. The present paper draws upon this earlier work and describes a study designed to probe in general detail the conceptual structures of a small sample of Year 12 physics students following instruction on circular motion.

INSTRUMENT

A 27-item test (multiple-choice plus extended answer), as described in Gunstone (1984) was used in the study.

SAMPLE

One state high school and one Catholic girls' school participated in the study; 23 students answered the test a few weeks after studying the topic in class. The sample is of course small, and no claims are made about the generalizability of the findings to the wider school population. I merely make the point that even this small sample has yielded an astonishing variety of alternative conceptual frameworks that students use to account for the dynamics of circular motion.

FINDINGS

The 'correct', 'official', 'scientific', (i.e., Newtonian) framework

Before considering the vast collection of alternative explanations which students in these two classes offered we should note that a few students, following instruction, actually do accept the Newtonian view.

Student 8, for example, wrote

> The string exerts a constant, unbalanced force on the tin, which accelerates the tin towards the point to which the string is connected.

This student identified the force of gravity as the only force acting on Jupiter's moon, and stated

> The force ... acts at 90° to the motion of the moon (directly towards the centre of Jupiter).

Only two students (out of 23), however, offered consistent Newtonian explanations of this kind. These explanations may be regarded as 'complete' in the sense that they correctly identify both the direction of the force causing circular motion, and the nature of that force (tension, gravity).

Partial Newtonian Frameworks

A few students offered Newtonian explanations, but failed to explain the physical basis of the force: i.e., they may have recognised that an unbalanced, centripetal force is acting but they did not describe the nature of that force. The distinction is important. Warren (1979, p. 10) reports that some students describe the centripetal force on a satellite as equal to the gravitational force, but in terms which imply a belief that these are two different forces. In our study, Student 5 offered an answer which could be classified as partly Newtonian:

> The centripetal force acts on the tin continuously changing the direction of motion of the tin. The force is directed towards the centre ... The velocity is constantly changing because the direction of motion is changing. There[fore?] there is a force acting on the tin.

And, a similar response from student No. 14:

> Centripetal force is the one acting towards the centre of the circle to keep it in its circular motion.

Note that there is no mention here of the physical basis of the force: the word 'centripetal' is used as if it were a description of a type of force, rather than simply a synonym for 'towards the centre'. Both students' explanations contain tautological propositions. However, both students were able to explain the Jupiter/moon situation in terms of 'an attracting force between Jupiter and its moon' which is 'directed towards Jupiter'.

So much for the good news. The remainder of the discussion of findings is devoted to the many alternative frameworks which students employed to make sense of circular motion.

Shades of Aristotle: The Motive Force Framework

Watts (1983), in a study of the conceptual frameworks about force of 12 secondary school students aged 11-18, noted a common belief that forces are required to cause and maintain motion: 'If a body is moving, there is a force acting upon it in the direction of the movement' (p. 226). Some pupils consider this force to be a net force; others make no such distinction.

This motive force framework can be found in some students' explanations of circular motion. Student 17, for example, agreed that there were forces acting on Jupiter's moon - 'the gravitational field strength pulling it in' - but then said that the total force was 'not zero, and in the direction of motion ... because it is moving'. This student had earlier given similar accounts for the total force acting on a tin sliding horizontally at constant speed and on a car travelling along a straight road at constant speed. In a later question on earth satellites, he wrote about 'the force that would make the satellite go in a straight line' as a force which is acting on the satellite.

The common theme here is the Aristotelian idea that forward motion requires a forward force. Other Newtonian concepts - gravity, friction - have been grafted on to this conceptual structure without disturbing it too much.

The Equilibrium Framework: Type I - Absence of Radial Forces

Many students regard circular motion as a phenomenon in which the moving object is in some kind of balance, or equilibrium. Circular motion at constant speed is treated much like rectilinear motion at constant speed. This belief in equilibrium is expressed in at least two distinct ways. One is to avoid all reference to radial forces, as if the constant speed of the object is the dominant characteristic, and the changing direction is simply not a phenomenon requiring a dynamic explanation at all.

For Student 21, for example, there were three forces acting on the revolving tin: weight, normal (reaction) and a friction force (backwards). Her diagram contains the word 'tension' but there is no arrow to show direction, and the word has been crossed out from the list of forces acting. For Jupiter's moon, this student believed that there were no forces acting at all: the moon 'is in space, therefore no friction, therefore according to Newton's law this body will not change its speed unless acted upon by an external force. There is no acceleration, therefore force = 0'.

Equilibrium Framework Type II: Two Counter-Balancing Radial Forces

A second, more complex manifestation of equilibrium can be seen in explanations which postulate a balance between a centripetal force and an equal and opposite centrifugal force. These explanations probably stem from attempts by students to integrate the new knowledge (a centripetal force acts on a revolving body) with a firmly held prior belief in equilibrium.

The 'counter-balancing' account of circular motion has already been noted by Viennot (1979):

> The circular motion of a stone on the end of a string ... is incorrectly seen as an equilibrium situation (radially) so that there is an intuitive need for two 'equal' and opposite forces.

Student 3 provides a clear example of this. He drew four forces acting on the tin (weight, normal reaction, inward force labelled 'F_1 = ma' and an outward Force F_2. The total force, he said, was zero: if not 'the tin will not go in a circle but in [a] different direction'. Similarly, the total force on Jupiter's moon was zero: 'If the centripetal force is greater than the force spinning [?] outward, definitely the moon will collide [with] Jupiter'. The physical basis of this outward force, it will be noted, is not explained: it is simply something which appears to be necessary to prevent something else from happening.

Inconsistent Frameworks: Newtonian and Non-Newtonian

Some students' responses show evidence of inconsistent frameworks: an answer to one question may be couched in Newtonian terms, but an abiding belief in equilibrium takes over when a slightly different question is asked. Student 13, for example, when asked for a description of forces on the revolving tin gave an apparently perfect Newtonian reply:

> There are several forces acting on the tin. The tension in the string produces a centripetal force which acts inwards, towards the centre of attachment of the tin. The forces due to gravity (the weight force) and the reaction force of the table (as previously described) continue to act. [In an earlier question, these two were described as summing to zero.]

Nevertheless, when asked for the total force on the tin, he answered:

> Zero ... the object moves with constant speed around the circle. Hence there cannot be any unbalanced force acting.

He treated the motion of a car on a circular road in a similar way:

> ... constant speed ... no unbalanced force. The centripetal force is balanced by a force acting in the opposite direction 'wanting' to keep the car moving in a straight line. Hence sum of all forces equals zero.

Rationales Underlying the Equilibrium Framework

Why do many students believe that a revolving object is in equilibrium? Viennot (1979) proposes an explanation in terms of an assumed linear relationship between force and velocity: zero velocity implies zero force. Thus, if an object has no radial velocity, then it has no radial force acting on it. Viennot was investigating the thought processes of university students. In the present study, however, it would appear that less complex beliefs are held by students who adopt an equilibrium framework. Two such beliefs emerge in some students' accounts:

- Constant speed implies no acceleration and hence zero net force.
- A force is required to hold a revolving object at a fixed distance from the centre.

Student 13, cited earlier, is quite explicit in offering the former belief:

> ... the object moves with constant speed ... hence there cannot be any unbalanced force ...

Student 16 exemplifies a belief in the second proposition:

> [There is a] centripedal [sic] force between moon and Jupiter. Force towards Jupiter, pulling moon towards Jupiter and force holding moon where it is.

Student 19 combined both beliefs in her account. She drew four forces on the tin, and integrated a misuse of Newton's second law with her misconception about equilibrium. The total force, she said, was zero, because

> it is moving in constant speed, hence the acceleration is equal to zero. As $F = ma$ it implies that the force is equal to 0. The other force which tend to equal both the opposite sides $A = B$, $C = D$. This helps to maintain the position of the tin.

Her account of Jupiter's moon is more complex:

> the moon is mov[ing] in a circular path, which means that Jupiter should have some kind of force acting on the moon in order to maintain ... [it] ... in a circular path. (Actually I never know whether this is true or not, I just guessed it.)

But equilibrium-as-position-maintenance wins out: the total force is 'zero' because it is moving in a constant speed, and always with the same distance from Jupiter.

The Physical basis of the mythical centrifugal force

If one holds strongly to a Type II equilibrium framework, there is an obvious need to introduce an outward (i.e. centrifugal) force; some students carry this through to the point of 'explaining' the physical basis of this force. Various explanations are offered:

- A second gravitational force

Student 23 deals with the revolving tin by labelling four forces: the weight, the normal reaction, and 'a centripetal force A which is of the same magnitude but different direction to B, the centrifugal force'.

In the case of Jupiter and its moon a physical 'explanation' is not introduced: the [total] force [on Jupiter's moon] is zero since the moon does not leave its orbit. The force exerted by Jupiter is equivalent to that exerted by the sun.

- Misuse of the action-reaction principle

Some students attempt to 'explain' centrifugal force by appealing to Newton's Third law.

Student 13 (whom we encountered earlier with his beautiful Newtonian account of circular motion, followed by the statement that the total force on the tin is zero) now gives us an insight into the basis of the extra force in his discussion of the Jupiter/moon problem:

> The only force on Jupiter's moon ... is the gravitational force on it exerted by Jupiter. The moon, itself, exerts an equal and opposite gravitational force on Jupiter; the total force must be zero.

It is unclear from this whether he believes that the total force on the moon is zero, or that he has misunderstood the meaning of the term 'total force'.

It is of course true that there is a centrifugal reaction force acting, but it acts on the object at the centre of the motion, and not on the revolving object. The action-reaction explanation stems from a failure to distinguish between these two sets of forces.

Some unusual conceptual frameworks

A few students wrote replies reflecting quite unusual conceptual frameworks:

- Centrifugal plus Aristotle

One student (20) combined centrifugal and Aristotelian concepts:

> The tin moves in a circle so a centripedal [sic] force and a centrifucal [sic] must be applying ...

This was followed by a diagram in which a constant magnitude resultant force acts in a tangentially forward direction. The total force, she states, is not zero, because 'the resultant of the forces applied (vector) is continually changing direction'.

- An Aristotelian yet anti-centrifugal framework

Student 1 postulated no less than six forces acting on the revolving tin: gavity, normal reaction, an inward force 'due to the acceleration in towards the nail', an outward 'tension in the string caused by inertia', 'friction if it is present' (tangential, backward) and 'inertia producing tension in the string' (tangential, forward). Apart from the false dichotomy between the tension and the centripetal force in this response, the reply suggests that the tengential velocity/momentum of the tin is being treated as if it were a kind of forward driving force. Later, in discussing eareth-satellites, he asserts that the

> satellite has momentum. This produces inertia, which combined with gravity keeps the satellite in orbit.

This student does not believe in centrifugal force:

> [It] is non-existant [sic]. It merely explains the apparent effects to ignorant savages. All motion can create forces. Impetus is a force. Momentum is a force. Kinetic energy is a force.

- Centrifugal friction

Student 7 gave clear Newtonian accounts of the motions of the tin and Jupiter's moon, and recognised that in the case of a car on a circular road, there was a non-zero centripetal force. However, his diagram of the forces acting on the car showed an outward frictional force in addition to the centripetal force. This explanation fails of course to recognise that the centripetal force here is frictional; the misconception would seem to stem from a belief that friction always acts in opposition to some other force acting on an object.

Student 16 (who believed there was a force 'holding the moon where it is') maintains a similar view about cars on circular roads. Like Student 7, he explains the motion of the car in terms of a centrifugal frictional force.

No consistent conceptual framework at all

And finally, some students do not appear to hold to any consistent conceptual framework at all. Individual situations are treated idiosyncratically, without any overall logical coherence.

Student 11 provides a clear example of this. An equilibrium situation - a tin sliding horizontally at constant speed - was treated as a non-equilibrium situation:

> The tin is not still, therefore there must be some net unbalanced force acting on it ...

But a non-equilibrium situation was treated as a Type I equilibrium situation. For a car travelling on a circular road, this student proposed a four-force explanation: weight, normal reaction, forward driving force, backward frictional force, but no radial force. The total force, he stated, was zero.

The Jupiter/Moon problem was then treated as a Type II equilibrium situation: he recognised 'there is the force of gravity pulling it in towards Jupiter', but then stated that the total force is zero because 'it does not move inwards or outwards from Jupiter'.

CONCLUDING NOTE

This exploration of the thoughts of 23 Year 12 students leads to a simple conclusion. The ghost of Aristotle must be dancing with mirth, for two millennia later his ideas are alive and well. Newton, on the other hand, must be turning in his grave.

To end on a more practical note, however, the findings suggest that teachers should recognise that the topic of circular motion is conceptually extremely difficult, and that students come to it (and leave it) with a wide variety of explanatory concepts, most of which are - in traditional Newtonian terms - plainly wrong. Since the dynamics of circular motion are central to a proper understanding of so many aspects of physics, there is a clear challenge to science educators to devise some more effective instructional procedures.

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SELECTIVE CUEING AMONG CHEMISTRY TEACHERS

Peter Fensham

INTRODUCTION

A few years ago the Karplus duo introduced a number of Australian science educators to some detailed activities (Karplus et al., 1977) for the inservice education of science teachers. Since that time I have used one of these activities with groups of Diploma in Education students on several occasions. This has resulted in confusing experiences for the students and the teacher educator. In 1983 the opportunity arose to use this activity much more widely throughout Australia and a more systematic means of recording the responses of teachers during the activity was devised.

This paper reports the findings of these inservice experiences and discusses them in the light of three recent analyses by Fensham (1984), Nelson (1983), and Kass and Jenkins (1982) of varieties of chemical knowledge and teachers' priorities among them.

The findings provide a useful base for planning the continued inservice education of chemistry teachers for the demands society is now placing on science curricula.

The Inservice Activity

The activity involves the participants in four different tasks or Stages:

1 the prediction of events in an apparently simple and familiar chemical system;
2 the provision of the chemical knowledge on which their predictions are based;
3 the observation and 'measurement' of the reacting system and
4 the provision of chemical explanations that are consistent with what has been observed.

The chemical system is shown in Figure 1. It consists of a wad of kitchen steel wool which has been thoroughly dampened with dilute acetic acid (vinegar will do) and wedged in the centre of an inverted test tube connected via a stopper and tube to a beaker of water. This diagram and the apparatus itself is quite familiar to all participants at the levels tested and is recognised as a means of monitoring gas uptake or evolution, but the chemical system as a whole was new to all these teachers.

FIGURE 1

The reaction system for prediction, observation and explanation.

In Stage 1 the participants are given a sheet with the diagram shown in Figure 1 on it and two spaces, (i) for their predictions and (ii) for presenting in Stage 2 the chemistry behind their prediction. The system is also verbally described to them and the apparatus and the reactants are displayed. No problems with comprehension were reported at this point. The task of Stage 1 begins after the instruction, 'I want you to write down in the first space on Sheet 1 all the observations and measurements that you expect to make when you establish this reacting system'.

When this task is completed the instruction for the task for Stage 2 is given. 'Now write down the chemical knowledge that are the bases of what you expect to observe'. This record sheet is then collected and the participants then are given a second record sheet, a set of the apparatus, the reactants and begin to establish the reaction system. For this Stage 3, the instruction has been 'Set up the reacting system as in Figure 1 and observe and measure it in whatever way you think will be useful. Record these results on the first half of Sheet 2'.

The activity has been carried out in well equipped school laboratories so that timers, balances, rulers, measuring cylinders, thermometers, and other chemicals were all obviously accessible.

During and after the surprising (to the great majority) events of Stage 3 (about 20 minutes) and for Stage 4 the period afterwards, the participants are given the final instruction. 'Provide in the second half of Sheet 2 a chemical explanation of the various observations and measurements you have recorded'.

In the 1983 inservice sessions, the participants at the end of the activity were asked to complete a chemical knowledge test consisting of items drawn from potentially relevant physical chemistry, the descriptive chemistry of the system itself, and the practical experience of establishing the reacting system.

The Reaction System

The usual observation in Stage 3 is for the water from the beaker to start to rise up the connecting tube within a minute or so of establishing the system. Occasionally the level of the water in the tube will decrease and a bubble or two may escape from the bottom of the tube before the rise begins. The level in most cases rises quite rapidly and at a more or less constant rate for about 15 minutes by which time it will often have entered the tube itself where its rise continues until a fraction that is more than a tenth of the tube contains water. During this time droplets appear on the walls of the test tube below and particularly above the wad of steel wool. The steel wool changes colour in patches to varying shades of brown especially where it is not in contact with a film of liquid such as is seen where it meets the walls of the tube. There is also a quite definite temperature rise for the surface of the test tube that is close to the wad of steel wool. These are the common and readily available events to be observed and measured in Stage 3.

The dominant reaction is thus the rusting of the iron which continues until the oxygen in the system is used up. The dilute acetic acid serves to dissolve the oxidised surface of the 'steel wool' (iron wire) and on the large cleaned surface area the rusting reaction proceeds quite rapidly. Because of the large available reaction surface the rate is more or less constant or zero order. The exothermic reactions raise the temperature of the wad and the neighbouring part of the glass tube. This energy also vaporises water from the wad which condenses on the cooler parts of the tube.

Sometimes a film of water forms where the wad presses against the glass walls and it is noticeable that rusting does not appear in these regions where the iron is effectively immersed in water and shielded from the other reactant, oxygen.

RESULTS

The two groups (I and II) of teachers who provided these data consisted of 27 and 31 members but not all provided reports in each stage of the activity.

Stage 1

About 20 different observations or measurements were suggested across the two groups. Only a few of these are mutually exclusive so the very small numbers reported by any one teacher (see Table 1) indicate the tendency they have to see this open ended problem in a convergent manner.

TABLE 1

The response rate of the two groups of teachers predicting what observations will be made

	Number of predicted observations					
	1	2	3	4	5	
No. of teachers reporting	2	15	4	3	2	Group I (n=26)
	1	13	8	8	1	Group II (n=31)

The great majority of each group perceived the system as metal and acid reacting to give hydrogen. Their expected observations were thus bubbles through the beaker water and either the colour change of the Fe^{2+} salt formation, a subsequent rise of liquid up the tube, or a physical change in the metal (e.g. its surface will change, its mass will become smaller or lighter as it is buoyed up with hydrogen, etc).

In Group I only one teacher predicted rusting as the reaction and another one expected hydrogen evolution and subsequent rusting. In Group II, two teachers expected rusting and three teachers expected both reactions the competition of which would determine the movement of liquid in the tube.

Table 2 summarises the teachers' predicted observations.

Stage 2

Because of the simplicity of the predicted observations in Stage 1 most of the teachers wrote down the equation for hydrogen formation and some related explanation for their other prediction(s). An unusually complex explanation is shown in Box 1.

TABLE 2

The types of predicted observations and their frequency among the teachers

Predicted Observation	No. of teachers reporting	
	Group I (n=26)	Group II (n=31)
Bubbles of hydrogen gas from tube	21	23
Colour change of metal		
to Fe^{2+} or to salt	10	11
to brown Fe^{3+}	5	4
to rust	2	5
Physical change in metal	3	14
A heating effect near metal	3	8
A smell of H_2S	0	1
Formation of CO_2	1	0
A colour change in water	2	0
Slowness in the changes	3	3
A rise in the water level	3	7
A lowering of the water level	1	6
A subsequent rise of the level	6	3

BOX 1

A teacher's account of the chemical basis of his/her predictions for the system (a complex example)

$Fe + 2H^+(aq) - Fe^{2+}(aq) + H_2(g)$
Reaction is exothermic
Corrosion → green Fe^{2+}
Corrosion 'eats through' thin strands and some fall off
Wool + H_2 less dense → gets pushed upwards (Archimedean upthrust)

Stage 3

The reporting of the observations for this stage is dominated by (i) the unexpected rise of the water up the tube (and in many cases into the reaction test tube itself), (ii) the condensation of liquid droplets that forms on the walls of the test tube both above and below the wad of steel wool and (iii) the browning that appears on the parts of the surface of the wad as the reaction proceeds. Nevertheless, not all the teachers reporting (i) added the observations (ii) and (iii). Some reported instead the warming of the test tube in the vicinity of the wad or some other feature (see Table 3).

The observations or measurements listed in Table 3 give rise to 12 potential responses and all but the colouring of the liquid and the initial bubbling could have been made in each of the teachers' reacting systems. The number of observations reported by the teachers in the two groups is given in Table 4.

TABLE 3

The types of reported observations and their frequency among the teachers

Reported Observation	No of teachers reporting	
	Group I (n=26)	Group II (n=22)
Water rising in tube	26	22
Extent of rise	4	5
Rate of rise	1	0
Condensation on walls	18	14
Location of condensation	7	4
Colour change of metal	21	18
Location of colour on metal	1	1
Warming of tube in places	10	12
Cooling of tube in places	1	0
Changes in water	3	3
Bubbles of gas	0	4

TABLE 4

The response rate of the two groups of teachers to the task of observing and reaction system

	Number of predicted observations					
	1	2	3	4	5	
No. of teachers reporting	-	5	12	4	5	Group I (n=26)
	-	1	11	6	4	Group II (n=31)

Only one teacher reported on the kinetics of the reaction and none of the teachers actually measured the rate. Very few of the teachers discriminated about the location of the condensation, the differential browning of the surface of the wad. Nobody asked for a second apparatus to set up a comparative system using stronger acid or distilled water.

Stage 4

A common type of explanation was 'solution of iron in acid and oxidation of iron by air using up oxygen hence lowering pressure causing water to rise up tube'. A minority in both groups used the word 'rust' in their explanations, most referring to oxides of iron or Fe_2O_3 for the brown colouration and the product of the oxygen uptake. A number now recognised the acid as cleaning oxide from the surface of the metal or acting as a catalyst. A number (but by no means all) attempted to relate the observation of an exothermic reaction to the very evident condensation on the cooler parts of the test tube wall.

Post-test of related knowledge

The great majority of both groups had the factual knowledge of the rusting reaction that might have led them to expect it to occur and to explain the patchiness of the brown colouration.

Two thirds of each group knew that 'the kinetics of a reaction is important data for its mechanism'. At least two thirds were well able to calculate the stoichiometry of the reactants and to recognise that oxygen would be the limiting reagent in rusting and acetic acid in the hydrogen reaction if it occurs. Neither of these parts of their knowledge store were used by any of the teachers in prediction and only by two or three in Stage 4.

All of the teachers reported that their expected reaction was exothermic and almost all that the vapour pressure of water increases with temperature. These pieces of knowledge were not used in the predictions of Stage 1 and despite the observations in Stage 3 were rarely combined by the teachers in Stage 4 to explain what they had observed.

A surprisingly high percentage (52% of Group I, 44% of Group II) believes that 'the overall change in ΔH of a reaction is important data for its mechanism'.

Only one teacher in the two groups was unable to estimate the amount of energy that would be involved in the reacting system. In conversation during Stage 3, it emerged that very few knew or seemed to have thought about what temperature difference their fingers or skin could detect and a calorimetric synthesis of their observations and knowledge was beyond them.

DISCUSSION

The education in chemistry of most chemistry teachers has been an undergraduate degree with chemistry as a major or minor sequence. In most Australian universities and CAEs (producing teachers directly) there are no practical examinations and formal written examinations of the closed book variety at the end of each semester or year of work are the major determinants of these teachers' learning. Although many hours are spent in laboratories and in writing up practical work, these are not rewarded in any comparable way to the hours devoted to learning the theoretical and descriptive accounts of chemistry that are presented by lecturers on two dimensional chalk boards or are contained on the two dimensional pages of chemistry text books. It is the ability to replicate this theoretical and descriptive knowledge on a two dimensional examination paper that is the hallmark of chemistry learning and that in the end becomes the basis of whether these teachers become 'licensed' as able to teach chemistry in schools.

Elsewhere (Fensham, 1984) I have discussed this socialisation of chemistry teachers into a two dimensional view of chemistry as theoretical and factually descriptive. This occurs even though their own teachers in universities (at least) practise quite different views in which the practical, the problematic, and the unexpected are as common as the few pieces of theory they are working with at any time (Fensham, 1981).

It is thus not surprising that these teachers perceive a problematic system such as the one presented to them in this inservice experience as tasks for which they have to seek out one or two pieces from their knowledge store, i.e. the tasks, despite their open-wordedness, are reduced to being like examination questions. Once a piece of knowledge - 'the reaction by dilute acids and metals to give hydrogen' - has been chosen, the task is seen to be complete. It is of interest to note that the particular acid - dilute acetic acid - is not mentioned in most texts as behaving in this way nor is it likely that the teachers would have experimentally experienced acetic acid and iron producing hydrogen before. In the knowledge post test, 65 per cent of Group I and 48 per cent of Group II remained confident that this reaction occurs even though not more than nine of them experienced any evidence of gas evolution in Stage 3.

Nelson (1983) identified another gap in the nature of chemical knowledge that most teachers have acquired. This gap is to do with applications of chemistry in the real world or applied knowledge in general. He argues an eloquent case for a more integrated education of chemists and chemistry teachers in the pure and applied nature of chemistry.

BOX 2

The eight normative perspectives on the nature of knowledge in science (Kass & Jenkins, 1982), with examples from the reaction system

A	theoretical:	values theoretical knowledge and theoretical ways of knowing. acid plus metal gives hydrogen and oxygen plus iron (II) gives iron (III) oxide.
B	empirical:	values knowledge gained by empirical means. What many types of data will this reaction system provide?
C	applicational:	values practical knowledge and knowledge from applied situations. Steel wool for use in the kitchen has been exposed to oxygen for a long time. Steel wool rusts when left damp on a sink. Dilute acids are made from small amounts of concentrated acid and a lot of water.
D	methodological:	values the process and methods of gaining knowledge. the system is an open ended problem of several possibilities, the occurrence of which can be checked by making observations and measurements.
E	epistemological:	values knowledge of the limits and validity of knowledge claims. acetic acid probably belongs to the group of acids that gives hydrogen with metals but this will need to be checked and a negative outcome is possible.
F	social reconstructionist:	values social, political and economic components of knowledge and knowledge gained in social action.
G	psychological:	values knowledge meaningful to learner as active participant. this system is new to me so it provides a chance for an extension of my knowledge. It is not merely a question for which I should recall an answer.
H	pedagogical:	values effective and efficient ways of transmitting knowledge.

Kass and Jenkins (1982) in describing a basis for the development of materials for a chemistry curriculum in Canada listed a number of possible normative perspectives on the nature of scientific knowledge. These are given in Box 2 in which six of their eight perspectives have also been exemplified in terms of the reacting system for these inservice experiences.

As Kass and Jenkins argue, the dominance of one or other of these perspectives could lead to quite different curricular materials. They also point out most widely used school text books like CHEM Study and its derivatives are almost exclusively theoretical in perspective. The dominance of this perspective, they argue, tends to see chemistry as orderly and linear. Classroom situations are to conform to the textual presentation rather than the other way around. Deviations in practice are faults. Science consists of right answers.

It is such school texts that were the essential diet (when they were at school) and are now the teaching materials at the upper secondary level of the Australian teachers in this study. It is thus not surprising that the present school experience of the teachers does little to modify the socialisation into the theoretical perspective that they underwent so intensively in their tertiary studies.

From this perspective the choice of 'acid plus metal gives hydrogen' then determines all the other aspects of the tasks in Stages 1 to 4. The perspectives in Box 2 are not autonomous or co-acting. They become subsumed into the first one or distorted to the base of a narrow hierarchy in which the theoretical perspective is at the top.

As the examples in Box 2 attempt to show this inservice experience has great potential for the exercise of most of Kass and Jenkins' perspectives. The extent to which it did not would be a sobering thought for those who wish for a much broader curriculum for chemistry in schools.

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STUDENT TEACHERS' OPINIONS - A FOLLOW UP

Ken Appleton

INTRODUCTION

For some years concern has been expressed about the teaching of science in primary schools (Symington, 1974; Henry, 1977). Some teachers apparently do not teach science, and many use inappropriate strategies (Varley, 1975). Bratt (1977), Davies (1982), and others have suggested that part of this difficulty may be attributed to the teachers' attitudes to teaching science, such as their feelings of inadequacy arising from lack of science knowledge. Information regarding the origins of teachers' feelings of insecurity in science teaching may indicate the type of support needed for teachers in both pre-service and in-service programs. A previous study (Appleton, 1983) examined the opinions of pre-service student teachers at the beginning of their training regarding various teaching strategies in science. It was reported that the students generally said they preferred strategies which involved children in first-hand practical experiences with equipment (often referred to as hands-on activities), over those which did not. Further, these opinions seemed to have had their origins in the students' own learning experiences and schooling. Since the teaching strategies preferred by the students were generally different from the strategies used by most primary school teachers, one of several possibilities exists:

(a) Teachers who are recent graduates are different from most experienced teachers in that they tend to use hands-on strategies.

(b) Many students change their opinions about preferred strategies during their teacher training.

(c) Constraints within the school influence many teachers, even recent graduates, to change their preferred strategies - perhaps from what they would like to be able to do, to what they feel can actually be achieved.

To consider point (b) further, a follow-up study addressed the question of what effects a pre-service education course might have on the views of student teachers about the teaching of science. Its focus was twofold:

- What changes in students' opinions about selected teaching strategies in science occurred during the first year of a pre-service course?
- Did students who felt less secure about teaching science differ in their preferred teaching strategies from students who felt more secure about teaching science?

METHODOLOGY

A group of students was surveyed at the beginning of their Diploma of Teaching Course at Capricornia Institute of Advanced Education regarding their preferred teaching strategies in science (Appleton, 1983). The same students were administered an identical questionnaire at the completion of their first year of the science education course. The questionnaire included a scale (see Appleton, 1981) relating to their self-perceptions about teaching science. All 81 first-year students received the questionnaire but only 37 per cent responded. The low response rate may be partly attributed to a high student workload from course assessment at the time the questionnaire was administered. This could introduce some bias into the results, so conclusions reached should be treated as tentative. Some caution in generalizing from these findings should also be exercised, as the science education course taken by these students may not be typical of courses in other institutions.

The questionnaire (see Appendix 1) were scored from one (little or no emphasis) to five (a great deal of emphasis), and descriptive statistics calculated. These were then compared with statistics obtained in the same way in the previous study (Appleton, 1983). Changes in item means over the year were checked for significance using t-tests. Questionnaire items were also rank-ordered by means for comparison with the rank order of items obtained in the previous study. The attitude scale was also scored (the maximum possible range of scores being seven to 56), and was used to group the students for comparison purposes. Those who scored 40 or more on the scale were considered to have lower self-perceptions about teaching science. Statistics for the questionnaire items were then calculated for each group, to determine any differences in preferred strategies between the groups. Differences were examined by comparing means using t-tests, and by comparing rank-orders of items for each group.

The Science Education Course

The study was not intended as an evaluation of the science education course taken by the students, but an overview of the course may make some of the findings more understandable. While the course was designed to reinforce ideas about using a variety of hands-on strategies, it also suggested that children develop concepts through what they experience rather than through what they are told. The role of open-ended activities in contributing towards this was emphasized. Although the course was not specifically designed to challenge the students' views about teaching strategies, this seemed to occur for at least some students.

The course focussed on the following content areas:

(a) The science process skills. The students worked through activities designed to illustrate particular process skills, discussed these in tutorials, and selected several activities relating to process skills for implementation with one or two children in a school setting.

(b) Open-ended and closed activities. The students selected or designed several open-ended and closed activities for implementation with a small group of children. They compared the pupil interactions and outcomes for each type of activity.

(c) Development of concepts. Ideas about how children develop concepts were presented to the students, and were discussed in tutorials. This work was also related to their experiences with small groups of children in the school setting.

The course would be followed by two further compulsory courses in each of the students' second and third year.

RESULTS

A comparison of descriptive statistics and rank order positions between the pre-course survey and the post-course survey data is presented in Table 1. Questionnaire item descriptions are abbreviated for convenience. See Appendix I for the full item descriptions.

The first three items in rank order for the pre-course survey all relate to hands-on types of strategies:

Children learn process skills
First-hand experiences for information
Pupil experimentation

Similarly, the first four items in rank order for the post-course survey also relate to hands-on strategies:

Pupil experimentation
First-hand experiences for information
Pupils devise experiments
Children learn process skills

The item relating to pupils devising and conducting experiments changed from rank order position seven to position three and there were minor changes in position for the three common items.

A dramatic change in position occured for item seven, 'Teacher explaining', which moved from rank order position four to position 15.

TABLE 1

Comparison of Teaching Strategies

Item No.	Brief Item Description	Pre-course Survey Mean	Pre-course Survey St.Dev.	Post-course Survey Mean	Post-course Survey St.Dev.	Ranked Position	Significance
4	Children learn process skills	4.4	0.7	4.0	0.9	4	0.05
13	First-hand experiences for information	4.1	0.9	4.3	0.7	2	-
9	Pupil experimentation	3.9	0.9	4.3	0.7	1	-
7	Teacher explaining	3.9	0.9	2.4	1.0	15	0.001
10	Same activity, different groups	3.8	0.9	3.6	0.7	6	-
6	Children learn concepts	3.7	0.9	3.7	0.8	5	-
1	Pupils devise experiments	3.6	0.9	4.1	1.0	3	0.05
3	Worksheets as experimental guides	3.6	1.0	3.0	0.9	7	0.05
14	Books and notes for information	3.4	0.8	2.8	0.5	10	0.001
15	Teacher as information source	3.3	1.0	2.5	0.7	12	0.001
5	Children learn facts	3.3	0.8	2.8	0.6	9	0.01
12	Different activities, different groups	3.2	1.1	3.0	1.2	7	-
2	Teacher demonstrations	3.0	0.9	2.5	0.8	13	0.01
8	Children watch T.V.	3.0	0.9	2.6	1.1	11	-
11	Same activity, whole class	3.0	0.7	2.5	0.8	13	0.01

Significant differences in means, as highlighted in Figure 1, were detected for some items at the 0.001 and 0.01 levels. These could all be classed as non-hands-on strategies and all showed decreases in means from pre-course to post-course surveys.

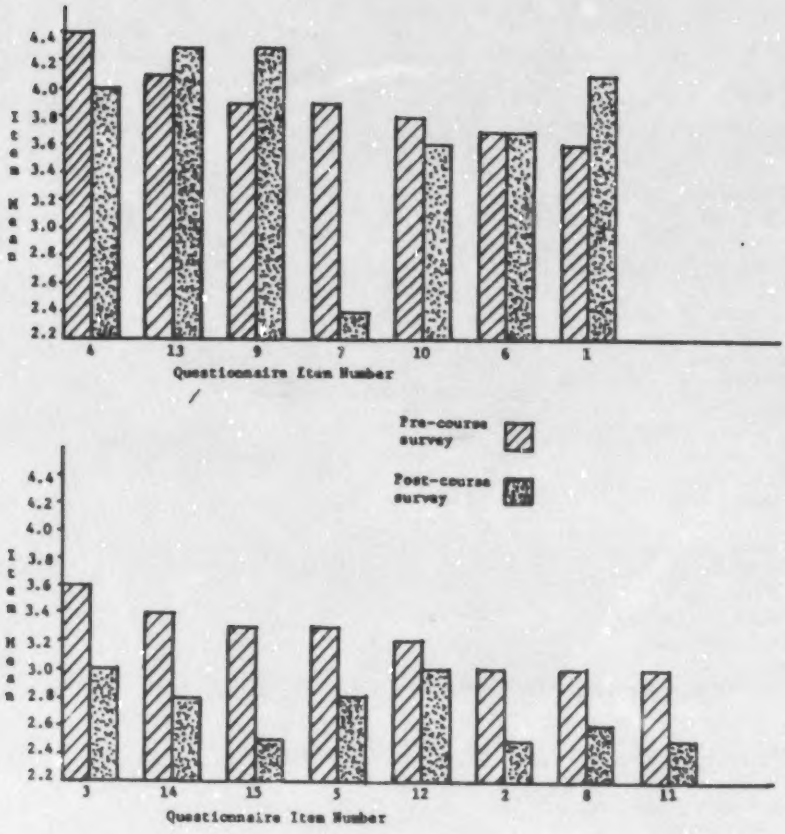

FIGURE 1

Comparisons of Pre- and Post-Course Surveys

Scores on the attitude scale ranged from 24 to 55. Figure 2 summarizes the questionnaire obtained by the group of students who scored 40 or more on the attitude scale (the high self-perception group), and the group which scored less than 40 on the attitude scale (the low self-perception group).

The same items appear in the first eight rank order positions for both groups. All eight items deal with hands-on strategies, or are compatible with such strategies. Means for those items were consistently lower for the low self-perception group than for the high self-perception group.

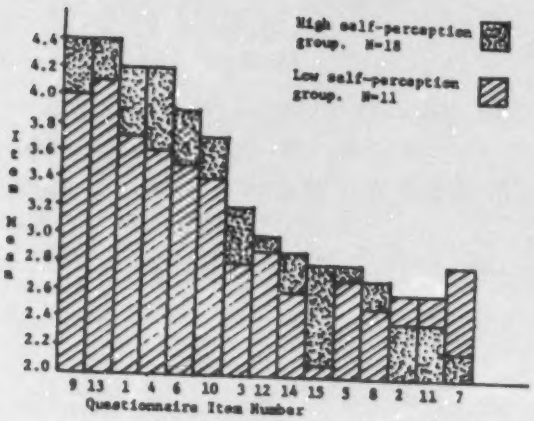

FIGURE 2
Comparison of Groups

The group with low self-perceptions of teaching science recorded higher means on the items relating to non-hands-on strategies, but the differences in means between the groups were not significant. Only two items showed significant differences in means between the groups (at the 0.005 level):

Children learn process skills

Teacher as information source.

The low self-perception group scored the lower mean for each of these items.

DISCUSSION

The group of students in this study showed no significant change in the types of science teaching strategies they preferred, from pre-course survey to post-course

survey. There was speculation in an earlier report (Appleton, 1983) as to whether a pre-service course may influence students to prefer non-hands-on strategies. However, this study has revealed that the first year of the students' education course had not influenced them to change their preferred strategies. Prior to the beginning of their course, they indicated a preference for hands-on strategies; and after the first year of the course the students showed a similar preference.

Even the least confident students appeared to become more positive about hands-on strategies, since the hands-on item means for this group in the post-course survey were at least equal to the item means of the whole group in the pre-course survey.

The course of study taken by the students seems to have reinforced their preferences for hands-on strategies. This was evident by higher means in the post-course survey compared to the pre-course survey in some items related to hands-on strategies, and by significantly lower means for several teacher-dominant strategies.

Some changes in the emphasis the students put on particular strategies reflected the nature of the science education units they had studied during the year. For example, the strategy of pupils divising and conducting their own experiments was more acceptable to students at the end of the year than at the beginning of the year. Conversely, the strategy of the teacher explaining what the children need to know was given a lower emphasis at the end of the year. Both issues were major considerations during the students' course.

There have been several reports on the poor state of science teaching in primary schools in recent years (e.g. Varley, 1975). Teachers do not usually employ hands-on strategies in science teaching, and many have low self-perceptions about teaching science. Prior to this study, a possible link between students with low self-perceptions in science teaching and non-hands-on strategies was anticipated. However, both high and low-perception groups gave greater emphasis to hands-on strategies than to non-hands-on strategies. It seems that, at this stage of their course, both groups of students who responded to the questionnaire indicated a preference for hands-on strategies. However, a difference of degree was evident between the groups. The low self-perception group scored lower means than the high self-perception group. This group tended to give a low emphasis to most non-hands-on strategies as well, but gave three of these items greater emphasis than the high self-perception group.

It is quite likely therefore that these students would have less determination to persist with hands-on strategies as difficulties arise in the classroom. School constraints present many difficulties in science teaching (Symington & Osborne, Note 1), so determination and commitment are necessary for a teacher to persist with using hands-on strategies. Consequently, those students who have poor self-perceptions of themselves as science teachers and who are less committed to hands-on strategies, may be the future teachers most likely to succumb to external pressures.

The students with lower self-perceptions about teaching science also scored significantly lower on strategies which might require an understanding of science (items 4 and 15). This supports the findings of Perkes (1975), Plimmer (1981), and others that teachers who lack confidence in teaching science perceive themselves as having an inadequate science background.

IMPLICATIONS FOR TEACHER EDUCATION

Although as stated earlier, there is a need for caution in generalizing from these results, some implications for teacher education emerge.

Firstly, it is unlikely that science education courses of the type outlined here have a negative effect on students' opinions about using hands-on strategies. The survey data in this study revealed that the course taken by the students generally had a positive effect on such opinions. This course would be typical of many such courses; and the students would be representative of most teacher education students. Hence it is becoming increasingly apparent that the problem of poor science teaching seems to lie more within the school than elsewhere.

Secondly, science education courses planned around the assumption that student teachers are generally against the use of hands-on strategies need to be re-examined. Some courses (if text books are taken as exemplars) seem to put considerable emphasis on an argument for some form of a hands-on approach. The assumption appears to be that because most teachers do not use the approach, then students need to be convinced that it is desirable. However, in this study, students generally stated a preference for a hands-on approach both before and after a science education course. Perhaps the time spent on trying to win students to a point of view which they already profess could be better spent on other activities.

Students who exhibit low self-perceptions about teaching science would be more likely to succumb to pressures within a school which make activity-based science

teaching difficult; especially since those students' opinions about hands-on strategies in this study were not as positive as their more confident peers. Consequently, such students may benefit from science education courses which offer practical solutions to school constraints. The more obvious need to improve the confidence of these students has been the subject of research for some years (e.g. Lucas & Dooley, 1982), but no conclusive findings borne out by actual teaching practices of graduates has emerged (Morrisey, 1981).

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APPENDIX I

What degree of emphasis do you think you would put on:

- pupils devising and conducting their own experiments whenever possible?
- the teacher demonstrating most experiments?
- pupils using worksheets as a guide to experimental activities?
- giving children practice in the thinking skills in science (such as observing, inferring, predicting)?
- encouraging children to remember important facts in science (such as the different parts of a flower)?
- helping children develop understanding of the important ideas in science (such as photosynthesis in green plants)?
- the teacher explaining to the pupils what they need to know?
- the pupils watching weekly science programs on television?
- experimental activities done by the pupils themselves?
- pupils doing the same science activity, but carried out by different groups in the class?
- pupils doing the same science activity, with the class as a whole?
- pupils doing different science activities, and carried out by different groups in the class?
- first-hand experiences with phenomena, by the children, as the major source of information in science?
- books and notes as the major source of information in science?
- the teacher as the major source of information in science?

Research in Science Education, 1984, 14, 167-172

HARNESSING ALTERNATIVE FRAMEWORKS IN TEACHER TRAINING: AN EXAMPLE FROM THE EARTH SCIENCES

John Happs

INTRODUCTION

Since the early use of terms such as 'alternative frameworks' and 'conceptual frameworks' many science educators have come to realise the influence that the learner's knowledge structures are likely to wield in the teaching-learning situation.

Numerous research papers have already provided detailed accounts of the alternative frameworks associated with individual science topics (e.g. Erickson, 1980; Novick & Nussbaum, 1981; Tamir, et al., 1981) whilst several collections of papers, covering a variety of science topics have emerged from research groups such as the Learning in Science Project at Waikato University (Osborne, et al., 1980) and the Children's Learning in Science Project at Leeds University (Brook et al., 1984). Additionally, other articles have offered collective summaries of findings, concerning alternative frameworks, from various scientific areas (Happs, 1983), with summaries of conference proceedings providing more detailed synopses (Archenhold, et al., 1980).

Teachers generally acknowledge that students, at different age levels, find certain scientific ideas difficult to understand and, although there may be some disagreement about the origins of these difficulties, few are likely to disagree that to identify the problem is to move toward its solution. Helm states:

> The teacher who has to cope with those holding the misconceptions may have both a negative and positive reaction. On the one hand, a given misconception represents a hurdle he may be expected to help the student overcome. On the other, the nature of the problem represented by the misconception may, if he is lucky, mean that its origin is identifiable, and if that is the case, he may be able to do something about it. (Helm, 1980, p.92)

Helm is using the term'misconception' here to mean those notions or ideas a learner may have about a topic, at any time, which are likely to be in need of modification or total replacement. Other terms which have been used synonomously with 'misconceptions', are 'children's science' (Osborne, 1980); 'alternative frameworks' (Driver, 1981); 'intuitive knowledge' (Strauss, 1981) and 'preconceptions' (Clement, 1982). Similarly, when workers talk of 'assessing children's concepts' (Nussbaum &

Novak, 1976); 'investigating layman's Science', (Shanon, 1976); 'exploring students' views of the world', (Osborne & Gilbert, 1980); 'research into common sense knowledge', (Vicentini-Missoni, 1980), and 'probing prior knowledge' (White, 1982), they are using such expressions to indicate a deliberate attempt to seek some common understanding of the learners' scientific conceptual frameworks.

The implications of the existence of alternative frameworks in the various scientific areas, and the consequent problems associated with bringing about conceptual change (Rowell & Dawson, 1977; Driver & Easley, 1978), suggest that a deliberate and specific kind of approach should be adopted when teaching some scientific topics. A number of 'critical conditions' have been pointed to by workers who are concerned with bringing about conceptual change (Strike & Posner, 1982). In the development of teaching strategies in the earth sciences, attempts have been made (Happs, 1984) to meet some of the conditions which should be attended to if learners are to accommodate better new scientific frameworks.

Bringing Learners' Views into Accord with Scientists' Views

The constructivist paradigm in learning (Driver, 1983) provides a rationale for the view that learners have personal ideas about natural phenomena and that these ideas are likely to prove difficult to shift. Interpretations from Piagetian research (Flavell, 1983) and the work of Wittrock (1980) and Osborne and Wittrock (1983) have led to a number of assumptions which may be made if teaching strategies are to be designed with the learner's position in mind. Some assumptions are:

(a) learning is concerned with students modifying or building upon existing cognitive structures. The development of these structures is affected, in ways that are difficult to predict, by different teaching strategies;

(b) learners will construct meaning through an interaction between their prior knowledge and stimuli from the environment;

(c) stimuli may be in the form of text, verbal information or the observation of phenomena. Such stimuli are rarely interpreted in exactly the way(s) in which the teacher intends them to be;

(d) teaching strategies cannot be designed so as to transfer knowledge directly into the learner's mind, rather they need to be designed to place the student in situations which assist him or her in the constructiion of scientific frameworks.

Some Considerations in Teacher Training

Vicentini-Missoni (1980) has pointed to the limited scientific background of primary teachers and the likelihood of science, being taught at the primary level, with an interesting 'flavour' of layman's science.

Secondary teachers, who are frequently called upon to teach outside their specialist subject area, may face similar difficulties (possibly to a lesser extent because of an increased awareness of the problem and their opportunities to consult informed colleagues). In order to address this kind of imbalance, there appears a need for teachers to be aware of:

(i) the learners' alternative knowledge frameworks concerning a specific topic area. As already pointed out, an increasing quantity of information is coming to hand in the various areas and this kind of information can be readily supplemented by having teachers carry out their own investigations into children's views concerning relevant topics. Additionally, curriculum planners in conjunction with professional researchers, could develop brief, yet penetrating surveys so that teachers might quickly establish the consensus views held by specific class groups, prior to formal instruction;

(ii) the scientific perspective of the same topic area(s). Teaching guides should provide relevant, easy to follow, background information so that teachers can clarify their own ideas about topics;

(iii) their own perspective shift. Teachers who come to use specific teaching materials for the first time may find that their views about a particular scientific topic are more closely aligned with the non-scientific perspective. This kind of realisation will doubtless raise awareness about the kinds of conceptual change that learners are about to face, as teaching proceeds.

HARNESSING ALTERNATIVE FRAMEWORKS

Information, concerning New Zealand primary and secondary students' understanding of terms such as 'rock', 'boulder', and 'sand', suggested that these words tended to be used in 'everyday' ways which were generally different from the scientific perspective (Happs, 1982). A subsequent study, involving graduate students (science and non-science) training for secondary teaching, showed that they held similar understandings about those terms. A summary of some of these views and how they compare with the scientific perspective appears below:

Scientific View	Learner's View
ROCK is largely used to depict a large fragment. Learners typically use the term in a non-scientific way whilst considering criteria such as 'colour', 'weight' and 'jaggedness' prior to identifying a sample as 'rock' or 'not rock'.	ROCK implies a rock fragment and both terms refer to natural material which comprises mineral aggregates.
BOULDER is often used to depict a very large, round piece of material - usually ore having rolled down a hillside.	BOULDER is a size term which refers to any rock/mineral fragment exceeding 200 mm in diameter.

Scientific View	Learner's View
SAND is usually taken to mean material on a beach or in a desert. Definite colours are often associated with the term, depending on the experiences of individuals, e.g. golden sands, black iron sands, etc.	SAND is a size term which to located refers any rock/mineral fragment between 2 - .02 in diameter.
GRAVEL is often taken to mean loose material located on the roadside, e.g. cars skid on gravel.	GRAVEL is a natural, loose accumulation of rock fragments with a size range of 2-50 mm in diameter.
CLAY is commonly regarded as being sticky, orange-coloured material found underground.	CLAY is a size-term, referring to mineral particles less than .002 mm in diameter.

Information about alternative frameworks, in the area of particle terms, has been used by this investigator to allow primary teacher trainees to compare their pre-existing ideas with the views held by primary and secondary students. These views were also compared to those held by scientists.

Teaching Procedures

Group discussion was encouraged to identify the reasoning patterns underlying those 'everyday' ideas, alongside a consideration of some reasons for the scientific approach to the allocation of such terms as rock, boulder, sand, and clay.

The importance of particle-size definitions to scientists was shown to the teacher trainees, in terms of the size analysis of different sediments, which provides important information about their origins and implications for commercial use and resource detection.

Soils were shown to comprise varying sand, silt, and clay-sized fractions which need to be determined in order that information can be made available about soil types, soil properties, and their potential for pasture growth, cropping building, and so on.

Activities, including the measurement and classification of particles found in beach sediments (commonly having a range of particle sizes from boulder-sand) and the settling out of different soil/sediment mixtures, readily provided students with an appreciation of the usefulness of the scientist's particle size scale. Each example of a particular particle type (where sighted, measured, and identified) was recorded so that students might compare the scientific terms with their previously held meanings for such terms.

COMPARING THE FRAMEWORKS

Teachers need to expose and discuss the different perspectives between the scientific and everyday views of any concepts; in this case, particle size terms. This will help pupils to clarify their own ideas and how their ideas compare with the scientific frameworks. The teaching strategies mentioned in this paper incorporated group discussions so that peer-interaction would provide each learner with contrasting points of view that might persuade him or her to justify or change currently held ideas. Teaching material should, ideally, include worksheets which can be used in discussion groups to encourage comparisons to be made between competing frameworks. This kind of situation was deliberately planned in order to promote student dissatisfaction with existing frameworks which initially would not allow material to be classified in a scientific manner. Thus the new (scientific) frameworks were seen to have problem-solving capacities. The opportunity to compare the two perspectives can and should be extended by providing further opportunities for pupils to transfer their newly acquired scientific frameworks. Materials and experiences should be provided for learners to use the scientific frameworks in other appropriate contexts.

The teaching procedures outlined in this paper appeared to be successful. Individual discussion with students indicated a firm grasp of the problems of alternative frameworks and an appreciation of the different perspectives involved in this particular exercise.

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THE SOURCES OF THEORETICAL PRINCIPLES FOR SCIENCE METHOD PROGRAMS: A NEW SETTING EXPLORED

Rod Fawns

THREE WAYS OF KNOWING ABOUT SCIENCE TEACHING

The quality of science teaching, it is suggested, can be improved by revising the principles on which it rests and on which we base our method programs. When the writings of Polanyi (1962), Oakeshott (1967), and Hirst (1983) are examined, we can deduce that, together, they suggest there are three ways of 'knowing about teaching': a 'common sense knowing' which is associated with reflection on rational actions, a 'disciplinary knowing' associated with the abstractions from the disciplines and a 'facit knowing' which is associated with personal knowledge of teaching. There are relationships between these three ways of knowing: they are assumed to be as shown in the schema presented on the next page. That schema also has certain implications for the conduct of science method programs.

The Schema and its Implications

1 Cycle A is the cycle of reflection and self-analysis in which the focal activities are those of planning, transacting, and reviewing. This cycle is stimulated in most students by 'conversations' maintained between the students, their pupils, supervisors, other students, and method staff. These conversations may originate in critique of tacit knowledge of students or in a commitment to practical principles based on the basis of certain common sense assumptions about teaching and learning.

2 Processes I and II are most likely to influence common sense knowing only in so far as Cycle A is operating and method staff are involved in the Cycle A conversations.

3 Initial teacher training programs dominated by assessment in psychology, philosophy, and sociology make assumptions about the autonomy of the disciplines. The operating assumptions are that process II and perhaps III will yield a practical theory about education; that these processes are by and large independent of concurrent Cycle A activity, and that process I is unimportant or unmanageable. It is suggested that the Cycle B processes are difficult to stimulate in isolation from Cycle A activity.

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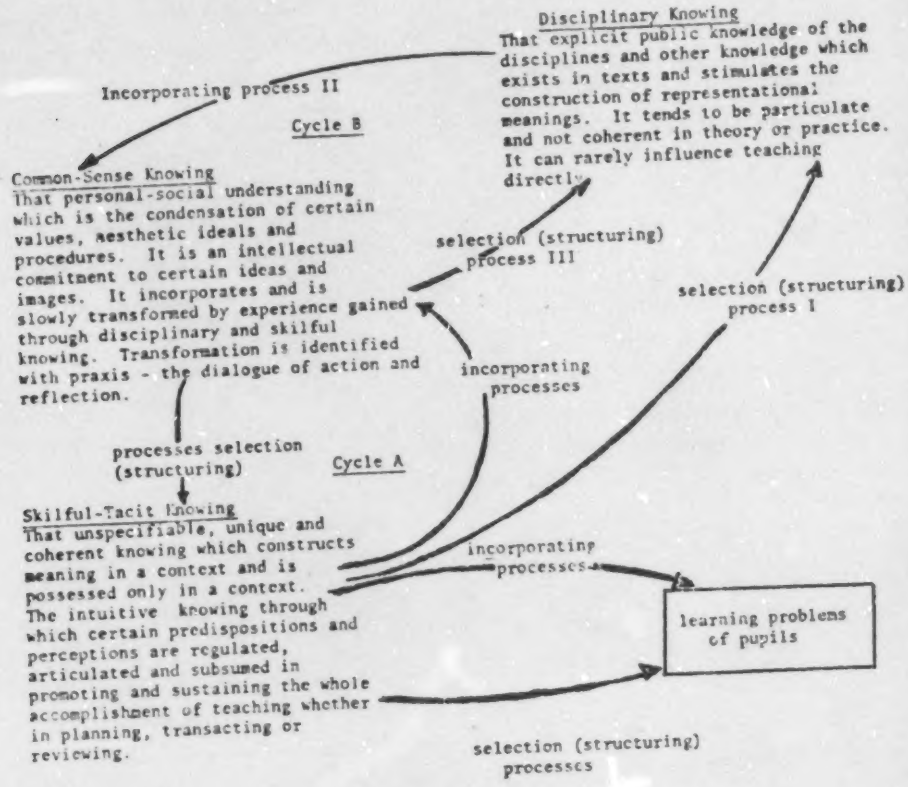
3 WAYS OF KNOWING ABOUT TEACHING SCIENCE (after Polanyi (1962), Oakeshott (1967) & Hirst (1983))


Disciplinary Knowing
That explicit public knowledge of the disciplines and other knowledge which exists in texts and stimulates the construction of representational meanings. It tends to be particulate and not coherent in theory or practice. It can rarely influence teaching directly
Incorporating process II
Cycle B
Common-Sense Knowing
That personal-social understanding which is the condensation of certain values, aesthetic ideals and procedures. It is an intellectual commitment to certain ideas and images. It incorporates and is slowly transformed by experience gained through disciplinary and skilful knowing. Transformation is identified with praxis - the dialogue of action and reflection.
selection (structuring) process III
selection (structuring) process I
incorporating processes
processes selection (structuring)
Cycle A
Skilful-Tacit Knowing
That unspecifiable, unique and coherent knowing which constructs meaning in a context and is possessed only in a context. The intuitive knowing through which certain predispositions and perceptions are regulated, articulated and subsumed in promoting and sustaining the whole accomplishment of teaching whether in planning, transacting or reviewing.
incorporating processes
learning problems of pupils
selection (structuring) processes

4 Learning from experience in Cycle A primarily involves observation and development of successful practices. Current practice in a school and the knowledge, beliefs, and principles characterising that practice are an important source of practical theory in methods teaching.

THE SMALL GROUP TEACHING PRACTICE

The preceding ideas have influenced a method program as the following account indicates.

Immediately following the second teaching round the small group practice is organised at Glenroy Technical School for 40 Melbourne University science method students. Pairs of student teachers are responsible for the teaching of a topic in one period a week for six weeks to a group of 4-5 pupils. Up to 8 student teachers work in a single room. All 40 students are teaching in the same 80 minute period in five junior science classes on a Wednesday morning. The students meet in the school an hour before the teaching practice to discuss strategies and compare diary entries. The teaching practice follows in which the groups in one room are videotaped. A final review using videotaped segments and diary summaries complete the session. The small group practice is thus part of a morning of practical discourse in which what is going on can be expressed. It has much in common with the discourse of everyday practical activity. It includes particular technical terms, beliefs, and principles concerned with specific educational practices but embedded in a wider discourse. The students receive broad topic outlines from the teachers who are asked to encourage student explanation of pieces of science and to keep a diary based upon the productions of the pupils in each teaching session.

The practical discourse between partners and method staff employs self-criticism and reflective analysis. The questions raised by Barnes and Todd (1977) are used to initiate this practical discourse; e.g.,

1 Where did the information, new ideas and suggestions come from? Were they mainly from you or from your pupils? Is this what you wanted?
2 Does what you say seem to match where they are? Do they understand? Were they able to use the lead you gave? Are you sure that you understand what they are trying to say? Did they find your help useful?
3 How did you receive your pupils' reports on what they had done, or their suggestions for alternative possibilities? Did you evaluate it as good or bad, relevant or irrelevant, true or false? If you did evaluate, were your responses mainly positive or negative? Did you pass over unacceptable contributions in silence? What do you think is the best policy?

4 If you did evaluate their contributions, what did you do with them? Did you use them as a basis for a new line of thought? Did you expand them yourself or ask the children themselves to expand them? Did you argue back, or put another point of view, or ask questions directing their attention to snags? Which of these things would have been most appropriate under the circumstances? Did you manage to do it? Sometimes? All the time? Were you able to encourage the children to be more explicit and clear than when they were alone? Did they talk at length, explaining where they had got to or did they just give short answers? Did you feel that others needed you too? Who did the summarising? Did you finally have to tell them the answer?

Diary Accounts

Keeping accounts was unexpectedly difficult for many. One reason appears to be associated with the way in which expectations of one's self, of children, and of the type and quality of lesson work were challenged by reality.

Examples of the shortcomings students experienced in their teaching have been derived from the diary of one systematic student:

> 'lack of scientific knowledge, slowness or failure to pick up the children's lines of thought; lack of imagination; bad questioning techniques; inability to give the children enough stimulus; inability to keep all five children interested - that is where we failed'.

In review sessions pairs of students attested to children's knowledge, and were clearly surprised by the discovery.

> 'They were completely different from classes I had taught - so interested but not in writing. Amazing understanding - we don't get a chance to work with that on rounds - this was particularly seen in their deliberations in the pollution game'.

The students were also surprised by the differences occurring in their small group.

> 'I was surprised that one boy would be so far ahead in things than the rest - better at everything we did'.

The challenge to handle a wide range of ability induced many students to invoke theories of cognitive development and openly reflect on cultural effects in the learning of science: from tacit skills out to focal principles. Generally the challenge of diversity was seen to demand more 'imaginative' teaching.

'The small group teaching needs more concentrated effort because the children needed independently bringing out. You need a lot of imagination to make each one come forward and enjoy himself - participate'.

Some students expected their group members to be more mature, to cooperate, to discuss as a group and to talk freely: they expected the small group practice to be like a university tutorial.

'I expected a bit more of a continuous conversation from them - they'd say a sentence and you'd have to ask them a question to get them to carry on talking about it. It sort of forced you into a role ... directing things rather than just talking about it and just them using the things they'd talked about'.

The adjustments demanded of the children by this manner of working were as severe as those demanded of the teachers. Physical closeness solved certain standard problems but raised others.

'Discipline rarely had to be enforced probably because there was always something to do and we were with them the whole time, face to face'.

Unusual student/teacher relationships developed in this ambiguous situation. On student reviewed the encounters this way:

'There was always a feeling of "you're the teacher we're the students" about, but they also had no hesitation in asking personal questions, or any questions at all. Completely out of the blue I was asked if my fingernails were real'.

The intimacy was certainly a challenge to many. One student remarked:

'You need to be careful with your words, you can see the reaction all the time at close range in their faces and they are freer to express what they feel. Compared with a larger class far more personal stuff - not quite teacher-pupil all the time - perhaps not a good think but another side of teaching came out'.

Many of the groups had weeks when everything went well and the children seemed interested. Then a really depressing week followed which produced a sense of failure in the teacher. The reasons for this seemed very personal, but changes of mood were more noticeable in the small group: a lack of enthusiasm by the teacher or a lack of energy due to bad health, quickly had an effect on the group. Furthermore, high expectations of some teachers sometimes resulted in a disproportionate sense of failure when set-backs occurred or when the children suddenly lost interest.

Relationships Between Partners

For some students collaboration was very difficult and for all it required considerable adjustment. For example, one pair, Tom and Ann, found that their attitudes to the children of Grade 8 and their preferred method of teaching were so different that their first lesson was a most frustrating experience. Ann felt she was under close personal examination and even sabotaged by Tom. Tom said little and wrote less and was all for 'seeing what the kids would do with this'. Ann was out to 'hand on what she knew'. They decided to alternate the lessons on the senses and Tom took the second lesson. He brought along a camera, lenses, and a Hodgson Light Box but didn't realize he would need to darken the room to get the effect he wanted. In Week 3 Ann brought along a range of specially selected foodstuffs and attempted to conduct a rigorous mapping experiment of the taste buds in each pupil's mouth. After this lesson Ann remarked that she disliked working with these children (i.e. Grade 8, and also the boys). She said she would rather teach them as a class of 30.

Although this cold charity continued without discussion or resolution to the end of the program Tom and Ann had to participate in each other's lessons due to the boisterous enthusiasm of the pupils, for example when Tom tried to get the group to organize a morse code relay. All the students were aware of the mis-match between Tom and Ann and the tension surfaced when Ann attacked the review sessions and the way I handled them. About half-way through the program Ann protested that she had been made ill in anticipation of the session and remarked 'Well at least I know how an intimidated, victimized little kid must feel sitting in class'. The review session became impersonal, much to my regret: strategies and behavioural responses rather than reflections, paradoxes, and speculations. I attempted to get around this by talking with individuals and pairs outside the sessions about their work. These conversations were always difficult to arrange and as they were no longer shared, seemed to lack excitement, complexity, and integrative meaning.

This was the most striking mis-match I have arranged. It resulted in almost complete rejection of a partner's skill and commonsense. In less extreme cases mis-match can result in one partner dominating and the other following.

Practical Theory from Methods Teaching

These accounts indicate that it is not easy to balance reflections and practice in methods teaching. The small group work is a completely absorbing experience for the student teachers, and yet part of its value is in analyzing what was done, and in developing skills of reflective observation (by carefully studying children, their relationships, and their learning); in short creating a context for explanation as well as skilful practice.

Sam and Jan were more reflective than most other pairs but they seemed to be speaking for most of their peers when they reviewed the small group sessions some four weeks later, during the next teaching round.

Sam 'What did I get out of the contact with the boys? Fun, I enjoyed working with them, observing them, reacting to the investigations and watching their level of interest. Trying out something different, how they would react with different situations ... With a class of 20 you can't observe each constantly. What do they see as proof?

Jan Now, as soon as I'm not in front of a class I try to watch closely - aloof from the situation, I think I've practised that a lot in the small group work. I find I can concentrate much more on what they're thinking while they're tackling a problem. You can't do that so much when teaching traditionally.

Fawns Did you encounter particular difficulties in small group teaching?

Sam The more difficult thing in teaching is the change from theory to practice - consistent and rapid change is the mark of a good scientist or good, anything else, theory - observation - theory.

Fawns Which theory do you mean - the theory which guides your practice?

Sam No that sort of theory can't be changed so quickly - there has to be consistency in how we act in all things.

It was difficult for Sam to acquire the tacit skill to allow him to produce the precise, appropriate concrete illustration or application of the scientific concept. Sam's view of current practice and values, and of science teaching mirroring scientific practice, suggests the value of the small group practice. For Sam the small group practice was about demonstrations. That tacit knowledge of practice and the contingencies, questions of social circumstance, student interest and background, are features any appropriate theory must accept. That appropriate theory changes slowly according to Sam, but it seemed to be the commonsense that Jan sought from the small group. According to several writers (e.g. Dow, 1979; Hamlyn, 1978; Hurst, 1983) educational practitioners must develop the appropriate theory to guide practice. A challenging question is whether current method programs induct teachers into discourses that help shape the theory.

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A PREFACE TO THE PHYSICS TEXTBOOK: AN HISTORICAL STUDY OF WHAT THE AUTHORS CLAIM

Paul Strube

Textbook writers often explain and justify their purposes to the public, to other educationalists, and occasionally to pupils through the Prefaces of their books. Here, for the only time in the text, the author speaks to the reader with an individual voice. After that (in the formalized physics texts at any rate) he or she vanishes from the work to such an extent that only cautious inference can uncover traces of a particular style or purpose. In Prefaces we have the opportunity to gain direct insight into the ideas of science writers as to the place of texts in the teaching of science.

Textbooks have become so integral a part of science education that the early disputes over their role and value are long forgotten. By the middle of the 19th century in Britain there was already a substantial number of works on secular and scientific material written for the general public (Layton, 1973). Most of these were very different in format and intent from the modern text. Yet as compulsory education increased the numbers of students and put new pressures on the curricula, the place of texts began to be more sharply debated. One of their greatest critics was H.E. Armstrong, whose advocacy of the importance of experimental science (Heurism) led to great changes in science education and teacher training particularly in the United Kingdom in the early 20th century. In his 1902 Address to the Educational Science Section of the British Association for the Advancement of Science, he comments on textbooks as follows:

> The teaching of the elements of experimental science must ... accompany the teaching of reading. The use of text-books must be most carefully avoided at this stage in order that that which should be elicited by experiment is not previously known and merely demonstrated - a most inferior method from any true educational point of view and of little value as a means of developing thought-power. (Armstrong, 1902)

Armstrong championed the importance of enquiry learning as opposed to content or knowledge-based learning, but it was not just the role of the text that concerns Armstrong, he also commented on the inappropriateness of the language of science in such texts:

> Text-books are not readable; in fact, they tend to spoil reading; and the majority of books are written for grown-up people having considerable experience of the world ... [It] is time that it were realized by those who could write well and accurately that there is a duty incumbent on them; on the other hand, something should be done to stem the torrent of text-books which is now flooding the field of education with the destroying force of a deluge, making proper reading impossible. (Armstrong, 1902)

These particular criticisms are still voiced today and need to be taken into account in any examination of Prefaces.

There are three major questions which the textbook authors would be expected to address. Firstly, the role of the textbook in science education; secondly the place of science education in the curriculum; and thirdly, the author's view of science as a type of human activity: what is its role in the life of the student and the community? In general these questions are addressed to the first of Armstrong's criticisms; questions of style and readability receive very much less attention. Earlier authors were understandably defensive against the concerns of Armstrong, yet all assume a secure place for the text in the classroom - they are not pleading for their lives. As the Nuffield experience shows, teachers want textbooks; the only question really of concern is which one.

In reading Prefaces of physical science texts several points are immediately clear. One, they are, almost without exception, written to match syllabus or examination demands.

> The work is designed primarily to cover the Intermediate Pass Course in Science, Engineering, and Medicine of the University of London, but it is also suitable for Intermediate Honours candidates and for University Scholarships. Further, it meets the requirements of the Civil Service Commissioners in connection with Junior Appointment, the Post Office (Engineers), and the Army Entrance Examination'. (Allen & Moore, 1918)

The above quotation is admittedly one of the most excessive. But it is echoed in Australian texts - 'This book provides a suitable course of study for the Leaving Certificate Examination in Physics, as prescribed by the University of Melbourne'

(Stump & Rowlands, 1950). One of its most common expressions is in the form of an address to particular students:

> The course provided in this single volume is designed as an introduction to physics and has been written with the needs of the CSE student especially in mind' (Chaplin & Keighley, 1977).

It may be argued that this characteristic, seen in texts separated in time by some 60 years, reflects only a convenient way for the authors to select content. What a textbook can accomplish, however, must surely be a function of what it contains. By making the text subject to the content demands of outside influence, the text serves a function that may be educationally unsound.

A clear danger is that the need to 'cover the ground' will force a style of rhetoric, or instructional methodology, inconsistent with wider educational objectives. A second point to clearly emerge is the perceived role of the textbook as a compilation of the important or unifying principles of physics in a convenient, readable form. The following selection is typical.

> The book is intended to meet the syllabus adequately without being excessive, and the systematic and compact presentation employed should simplify the task of the student to grasp the essentials of the subject with true understanding. (Barrell, 1958).

The essential character of this purpose is already succinctly summed up in the Preface to the very popular Textbook of Physics by J.D. Everett, 1901. He states the aim of the text as 'not so much to teach them many facts, as to teach them rightly to connect a few great facts together' (Everett, 1901). However, as the number of 'great facts' increased, the authors had to select from an ever-growing collection of material. One result of this can be seen in the Fifth Edition, (1970) of G.R. Noakes' New Intermediate Physics, which reached 965 pages. In his Preface, Noakes claims that the book 'ranged less widely' than the four separate volumes that preceded it, and that 'although the book is subdivided in the usual way, it really presents the subject as a coherent whole, by emphasising that the same basic principles apply throughout' (Noakes, 1970).

The majority of writers, in addition, see it as one of their purposes to point out the applications of scientific principles to everyday life; or, conversely, to use everyday experiences to build up increasingly complicated scientific concepts. This reflects an awareness of the long-standing conviction that science must be made relevant to the learner - a conviction that can be traced back to the time of T.H. Huxley:

> It appeared to me to be plainly dictated by common sense, that the teacher, who wishes to lead his pupils to form a clear mental picture of the order which pervades the multiform and endlessly shifting phenomena of nature, should commence with the familiar facts of the scholar's daily experience; and that, from the firm ground of such experience, he should lead the beginner, step by step, to remoter objects and to the less readily comprehensible relations of things. (Huxley, 1877, v)

This view, though clearly related to debates over the respective value of Pure versus Applied science, is more directly concerned with the child-centred pedagogical beliefs associated with the influential writings of Pestalozzi, and taken up by such men as John Henslow and Richard Daws (Layton, op.cit.). In this sense the text can be seen as responsive to models of child development and learning. Many texts emphasise the links to practical application in order to argue for relevance.

> ... care has been taken to stress the many illustrations and applications of physical principles in everyday life. To achieve a thorough understanding of these principles it is essential for students to have plenty of practice in solving numerical problems. (Smith & Smith, 1949)

Or this example from Kearsey's Certificate Physics, 1971:

> The treatment follows the course of discovery by experiment, and proceeds to the consideration of practical and technical applications. Many of the questions at the ends of the chapters are numerical. (Kearsey, 1971)

The distinction is a curious one - either we use the experiences of daily life to illustrate and illuminate the concepts of science, or we use the knowledge and concepts of science to illustrate daily experience.

Even in the many texts which make no explicit reference to learning theory, the ordering of the content reflects an attempt to take the reader from the simple to the complex, in analogy with personal development. The great majority of general physics texts order their content to run from classical mechanics through optics, heat, and hydrostatics, to electricity and magnetism. This is never argued to be in any way an historical ordering. The American PSSC text makes this point explicitly:

> The topics in the PSSC course are selected and ordered to progress from the simple and familiar to the more subtle ideas of modern atomic physics. (PSSC, 1960)

The Preface then goes on to outline the course as a growth of ideas and concepts, ignoring historical development. In fact, very few texts even argue that their content can or should be taken as random, or that teachers may use the chapters in any order. The unspoken assumption is that this is the order in which physics must be learned; the texts' role in science education is to support that assumption.

Science did not enjoy easy, automatic access to the school curriculum. The concerns of early 19th century educators with moral and religious instruction for very young students, and with Classical education for the select few, provided firm barriers to the introduction of a secular, scientific component to school programs. The strongest supporters of science education were themselves divided on the role it had to play and the form it should take. Though in general agreement about the benefits to the students of science education, they differed in their views on how these benefits were best brought about. For some, such as John Henslow and T.H. Huxley, the role of science education was to provide learners with a tool, the Scientific Method, which was to serve them in all aspects of their daily life. The method of science was the important thing. In contrast, for Richard Dawes and Henry Moseley science education could only inform us about science itself. Its range of usefulness was limited, and attention was therefore narrowed to specific areas of study (Layton, op.cit.). These concerns developed along with the rise of science itself as a powerful force in British society. Earlier works of science for young people had used scientific information to develop religious themes - the wide range of Catechetical, or Question and Answer texts, were commonly used in this way. But as science gained in prestige, its influences on daily life more visible, then the concerns of science educators became legitimized; the conflicts over the role of science education became sharper and more urgent of settlement. The textbook Prefaces often took sides.

> ... in my judgement, most of the elementary works I have seen begin at the wrong end, and too often terminate in an omnium gatherum of scraps of all sorts of undigested and unconnected information; thereby entirely destroying the educational value of that study which Kant justly termed 'the propaedeutic of natural knowledge'. (Huxley, op.cit.)

And almost 60 years later another Huxley was to continue the argument :

> We have wished to present science not as a 'school subject', but as a living body of knowledge which is interwoven into everything around us, whether machines or manufactured articles or the play of natural forces, whether the life of the fields or the mysteries of the laboratory'. (Andrade & Huxley, 1934)

These expansive claims must be seen in a wider content. They appear most commonly in texts written for younger students and non-examination courses. And they have gradually been replaced by texts that emphasise the 'concepts' or main 'principles' of the particular discipline, as we have seen. Indeed, after the First World War, physics textbooks increasingly see science education as the initiation of the learner into the paradigms of the sciences. The American texts, over the same period, maintain a view wider than this, however.

In general, the American writers have always been more concerned to justify and explain their textbooks - the prefaces are often long, carefully considering a wide range of educational issues.

> One purpose of this book is to provide an understanding of the principles of physics necessary to cope with the present mechanized environment ... Another purpose ... is to help young people lay a foundation for successful careers in the field of science ... A third purpose ... is to stimulate critical thinking as a basis for intelligent action in a democracy. We are forever concerned with the preservation of our American way of life ... In organizing and shaping the contents of this book, the authors have been guided by the report of the American Policies Commission ... in the direction of the four worthy aims laid down as a general pattern for education in a democracy. (Bower et al., 1942)

None of the British or Australian texts is this explicit. There are occasional references in earlier texts to a British need for well-educated and well-trained men and women, but these are confined to 19th century elementary works. The American text at least pays some attention to the placing of science in a socio-political context. They contain the idea that all educational disciplines can serve higher, or at least wider, purposes. Before being dismissed as blatant nationalism, or as a ritualistic incantation necessary to ensure publication and boost sales, it should be remembered that American authors were directly aware of and responsive to philosophical, psychological, and political aspects of education in a way not in evidence in British texts. It is tempting to assume that the American approach reflects their pragmatic view of science as a tool for 'better living'. Science serves the people, in support of a positivistic faith in the progress of discovery in science

and material well-being. This point has been recently developed by Smolicz and Nunan:

> The school text draws no clear distinction between science and technology; technological advance and scientific advance are taken as almost synonymous. Thus, school science, in stressing simultaneously technological advance and scientific method clearly embraces this positivistic ideal'. (Smolicz & Nunan, 1982)

American, British, and Australian authors generally hold one of two views of science. Either science is an ordered collection of knowledge held together by law and theory (and while the theories may progress towards truth, the laws are absolute) or science is the collection of techniques and hard-won data. Science is either Pure or Applied; Theoretical or Practical. The distinction was clear in 1901:

> This book is primarily intended as a text-book for elementary classes of Physics. It aims at presenting, in brief space, those portions of Theoretical Physics which are most essential as a foundation for subsequent advances, while at the same time most fitted for exercising the learner in logical and consecutive thought. (Everett, op. cit.)

Often associated with either view is an insistence on the necessity for plenty of numerical problem solving - from the working of such problems, comprehension grows. These numerical problems are 'designed to test physical principles, not mere arithmetic' (Kearsey, 1971), and many of them are taken from past examination papers. This combination of theory and problem-solving is typical of the view of science as an objective body of knowledge. Reference may be made to experiments, but often the laboratory work is placed in an accompanying laboratory manual which merely gives directions for practical work. The dynamic interaction between experiment and theory which characterizes science is missing.

The texts based on the experimentalist approach tend to emphasize the work in the laboratory at the expense of theory. Science consists for them of a set of techniques and skills for gathering data which is then used to generalize a law of nature. For example, an experiment is described that enables the student to measure angles of incidence and refraction for a light ray in air and in glass. This is taken as evidence for a law of refraction. And in the more naive texts, the assurance is given that such laws are somehow 'derived' from numerous experiments and calculations of this sort.

> The text-book is intended chiefly for the use of students who lay most stress on the study of the experimental part of Physics ... To bring the subject within the compass just described, an account is given only of phenomena which are of special importance, or which appear to throw light on other branches of Physics'. (Poynting & Thomson, 1925, vi)

Again and again the Prefaces in these 'experimentalist' texts stress that the emphasis should be placed on the practical, experimental side of science. Sometimes this is for the practical benefit of the student, the 'development of men and women capable of doing good work under adverse or unfamiliar circumstances' (Allen & Moore, op. cit.); but more commonly, because it is felt that experiments will elucidate theoretical principles.

Such texts take a view of science clearly expressed by the Macmillan Science Primers which, under the influence of prominent members of the Royal Society in the 19th century (the so-called X-Club: men such as T.H. Huxley, Gooker, and Tyndall), stressed the role of the laboratory, of the field study, as the bases for acquiring scientific methodology. From this may then come knowledge.

> ... the study of Physics exercises and sharpens observation: it brings the most exhaustive logic into play: it compares, abstracts, and generalizes, and provides a mental scenery appropriate to these processes ... lifting the national mind to the contemplation of that ... 'increasing purpose' which runs through the ages and widens the thoughts of men. (Tyndall, 1879)

In the previous sections, attention has been focussed only on issues which prevail in the majority of texts, but the Prefaces are revealing of other assumptions which are more individual or shared among a minority of authors. For example, some authors state their belief that the students will learn to think and reason more effectively after exposure to the method of science. Their text is written, they claim, in such a way as to facilitate this change in student behaviour. These authors are careful to assert that their text is not a mere resource book of information, but a tool of instruction. This was so at the beginning of the textbook's history - Huxley's seminal Physiography of 1877 makes this claim - and it is echoed in the Prefaces of the modern text.

In addition, most textbook writers take a rather conservative view of their role, especially in recent publications. Writing as they must for large classes of varying ability, and for use in classrooms of very different methodologies, this may not be surprising. One of the most popular and long-lasting textbooks, Gregory and Hadlee's Classbook of Physics (three editions, and 22 reprints between 1909 and 1941) states in its Preface that it is 'designed not so much to inspire as to instruct'. No modern textbook makes any greater claim. As the position of the text in science education became more assured, the writers gave less and less space to a Preface at all, limiting their comments to pointing out such changes to the text as

'the switch to SI units',
'the more extensive use of graphs and photographs',
'the inclusion of certain examination questions',
'the publishers' changes in format',
'the inclusion of new topics in line with syllabus changes', or
'responsive to teacher feedback':

> ... this edition is more in line with the modern approach to mechanics through multiflash photography and frictionless motion. These comments have guided much of the revision incorporated in this edition. (Mayfield et al., 1972)

A few early texts assumed their readers were going to be boys (i.e. Holmyard, 1930) but most are rarely specific concerning their audience except as examination candidates. A few texts state that they are designed with the 'average' pupil in mind. Noakes' New Intermediate Physics is a bit condescending on this point:

> It could be foreseen that the real need might be for a book which ... gave rather more encouragement to the average pupil in his struggle to understand the principles of Physics ... its success will only be judged by the extent to which it can stimulate such people to attack what is to them a difficult subject with enthusiasm and vigour. (Noakes, op. cit.)

Other texts appeal to the humanities students as well as to the potential future scientist (PSSC), or to engineering and medical students (Watson, 1970).

Few authors make statements about writing style and its relations to learning. As early as 1901 Thompson, in his Elementary Lessons in Electricity and Magnetism, was

stating his intent to present his material 'with sufficient clearness, yet with necessary brevity'. Gregory and Hadlee stated that 'A textbook should be concise in description and precise in instruction ...' Barrell wanted to be 'systematic and compact', Stump and Rowlands 'clear and concise', and Chaplin and Keighley believed that the use of colour and photographs would somehow make their text 'easily readable'. More attention, in fact, was paid to layout than to language.

What has been considered here has been only what the authors claim to be doing. What they achieved is a different matter. Textbooks for examination students, it can be argued, have not changed in substance for almost 100 years. The differences are of degree only. As seen, this parallels the vanishingly small differences between writers in their views of the text, its place in science education, and its role in their view of science over the same period of time.

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'EDUCATING RITA': IS AN ACADEMIC SCIENCE COURSE FOR PROSPECTIVE INFANT AND PRIMARY TEACHERS APPROPRIATE ?

Max Walsh, Paddy Lynch, Brian Jones, and Rex Kerrison

INTRODUCTION

It was decided to supplement the poor science background of ALL students enrolling in the Bachelor of Education degree in the University of Tasmania (1984) by offering them a substantial content-based science course based on the Open University S101 Science Course. This paper describes, in a case study format, the attempts to confront the range of problems which occurred as a result of the decision to implement the course.

COURSE CONTENT

The Open University S101 Science: A Foundation Course, is a multi-disciplinary one with contributions from physics, chemistry, biology, and Earth sciences. The S101 course was designed to be equivalent to six months of full-time study at first year university level and consists of 32 units of work represented as written readers. Twelve units were chosen for the pilot study, three from each of the sections dealing with physics, chemistry, biology, and geology.

Teaching Method

The teaching method employed was very similar to that recommended by the Open University except that new units, assignments, and all related materials were distributed to the student each fortnight (12 units in all). Two private study carrels were made available in the Education library each with a complete set of audio-visual materials including MAFS (Maths for Scientists), background notes, and slides showing major experimental techniques.

The Open University practical work is based on a series of home experiments using a home experimental kit supplied to each student. In our pilot version (1983) the relevant experiments were undertaken by the students in the laboratory. For the most part though, students were encouraged to work on these experiments in their own time with some minor consultation, and in future years we would hope to encourage extended project work. Each of the four sections, physics, Earth science, biology, and chemistry, had associated with them a major experimental component,

the results and interpretation of which constituted a major assignment. Direct staff student contact was timetabled for 2 x 2 hour sessions, one at the beginning and one at the end of each week.

The course was given by four staff members with particular strengths in physics, geology, biology, and chemistry. Each of the four sections was run by an individual lecturer but in 1984, with 95 students on the course, each lecturer is taking a tutorial group of 24 students for the full course and is acting as overall course co-ordinator for the area in which he has specialized. Our form of teaching offers advantages over the usual distance-learning arrangements in that students are in close contact with a tutor who is familiar to them and who, in turn, knows them. There is also the supportive atmosphere of a tutorial class which allows group discussion to readily take place.

ASSESSMENT OF STUDENTS - PILOT STUDY

Continuous assessment was employed which involved two take-home assignments, one involving the experimental components and several short class tests for each of the four sections. The Open University assignments were used where appropriate (or versions of the same). Students' final grades were obtained from a profile of about 20 class tests and assignments. Every attempt was made to give immediate feedback of this performance data.

A similar arrangement is being used in the course in 1984.

Evaluation of Pilot Study (1983) by Lecturing Staff

(i) Our first major observation is that we managed to cover a good deal of 'hard' science in the 24-week course. It is difficult to give a quantitative estimate but we would judge the content coverage to be 2-3 times greater than normally achieved. The majority of the conceptual notions was at a high level of sophistication, equal to that being given in first year science courses in the Faculty of Science. The students did find many of the concepts very difficult, particularly in physics and chemistry. However, in almost all cases the students made some intellectual gains even if they did not fully master all of the concepts. The readers (texts) were very well designed and the self-assessment questions throughout the texts helped greatly in assisting students to see where gains had been made and which of the objectives had been only partially understood.

(ii) Students were better able to cope with the biology and earth science sections than the physics and chemistry ones.

(iii) The students found some difficulty adjusting to the teaching technique and some did not come to grips with it at all. The school/college teaching environment is highly verbal and students were presumably highly conditioned to taking notes and saying little. This awkwardness towards dialogue and verbal exchange of ideas was not easy to break down but it did improve throughout the year. The students also took some time to adjust to the regular issue of fortnightly 'readers', each with a substantial content.

(iv) The sequence order of the four sections is important. We have very little choice but to begin with physics, even though we found that the 'measurement of astronomical distances' was not a popular topic with our students on our trial run. We favour the sequence physics, biology, chemistry, geology for a number of reasons.

(v) The assignments provided by the Open University, after a minimum of adaptation, represented an excellent course coverage. Many of the items and activities were extremely ingenious and thought-provoking. Both staff and students were well-satisfied with this aspect of the course, though colleagues will be aware that the assessment aspect is the bane of many courses. We are conducting examinations at the end of each unit during 1984 with a final examination to test all units.

Evaluation by Students

This evaluation component of the paper consists of two parts: a 30-item evaluation questionnaire given to all students (14/17 replied) during the final session of the pilot course run in 1983, and a 31-item formative appraisal questionnaire given to students (75/95 replied) at the conclusion of the physics component part of the total course offering in 1984.

The Pilot Study (November, 1983)

(i) The majority of students considered themselves to be 'about average' (11/14), 'fairly interested' in science (8/14), and to have worked hard most of the time. In other words they perceived themselves to be quite ordinary, middle-of-the-road students without a particularly strong orientation towards science.

(ii) The students varied in response to how fair they found the workload, 4/14 students responded that they found it a little too much and 3/4 much too much. However, they agreed that the readings were 'valuable' (10/14) and 'vital' to success (13/14).

(iii) The assessment system was considered to be 'about right' in terms of both difficulty (9/14) and a number of assignments (13/14). They considered that the assignments were 'always' related to the unit (8/14) and 'always' very fair and objective (9/14).

(iv) As regards improvement, they considered that they had learned 'as much' (6/14) or 'more' (4/14) than in other courses.

(v) The responses regarding 'interest' are summarised for item 22.

Item 22 How do you like this course compared with other courses you have had, including those you are now taking?

(a)	one of the best	1	
(b)	above average	4	
(c)	about average	3	
(d)	below average	4	
(e)	one of the poorest	2	N = 14

(vi) The student orientations towards content are also reported directly.

Item 25 What did you think was the most interesting and worthwhile part of this course?

Responses Physics (0), Chemistry (3), Earth Science (6), Biology (7).

(vii) Open-ended questions regarding the students' perception of personal benefits and instructional aspects indicated that several students did not like the teaching method employed and some, although they felt they had learned some general science, questioned its appropriateness for teaching.

(viii) Finally, 10/17 students indicated that they intended to continue with science as a major study in the second year (this is a far higher retention rate than anything that we have previously experienced). Three students failed the course.

A Formative Appraisal (April, 1984)

This questionnaire varied slightly to that used for the pilot study. No attempt was made in this survey to identify particular respondents to the questionnaire, and so the data represents group responses only. The major findings are reported here;

(i) The background data on respondents yielded the following: Two-thirds of the students are female: 37 per cent have not studied science beyond Grade 10; 28 per cent have studied only biology at H.S.C., and 13 per cent have studied three or more science subjects at H.S.C. prior to this course.

(ii) Forty-three per cent of students considered the workload was excessive, but 46 per cent were satisfied that it was 'fair'. Eighty-nine per cent considered the assigned readings were 'vital to success', and 69 per cent claimed to have read at least 75 per cent of them. Seventy-six per cent considered the readings were generally valuable.

(iii) The assessment system was considered to be 'about right' in terms of number of assignments (83%) and 'relevant to material covered' (97%). However, 57 per cent considered them 'too difficult', although 39 per cent were not troubled by them.

(iv) Fifty-one per cent agreed that their ability to think and criticise had increased as a result of the course, although 36 per cent disagreed. Seventy-one per cent felt that their level of knowledge had increased as a result of the course.

(v) The responses regarding 'teaching technique' are summarised in full.

Item 25 After studying the physics unit, do you feel you have now adapted to the teaching technique?

(a)	very much	6	
(b)	reasonably so	29	
(c)	not sure	22	
(d)	not much	14	
(e)	not al all	2	N = 75

Open-ended questions also indicated that the 'self-instructional' style was not popular although students were not prepared to label it as inappropriate.

(vi) Open-ended questions relating to the 'most interesting and worthwhile' and 'least interesting and least worthwhile' parts of the course yielded surprisingly consistent reponses. Students were very supportive of the 'astronomy' unit and their responses indicated that they had found it interesting, worthwhile, and likely to be applicable to their future teaching. They were almost all critical of the computation required in the second unit which is not surprising since we had recognised during the tutorial sessions some serious shortcomings in the average level of computational skill possessed by students.

(vii) The most heartening responses came from the open question 'Do you feel that you as a person are benefiting from taking this course? If so, in what ways?'

Seventy-Two per cent responded positively. Many students were aware that they had gained only partial understanding of many difficult concepts in physics, but they indicated that they were nevertheless pleased with the advances that they had made.

CONCLUSION

Our decision to choose the Open University S101 Science : A Foundation Course represents a direct attempt on our part to provide a background in science for our prospective infant and primary teachers. Our objective that this course achieve parity with first year Faculty of Science courses may appear to be an unattainable goal, given the methodological problems that have to be faced for such a general purpose course. It would certainly not be feasible for a lecture staff of four persons were it not for the printed readers, texts, assignments, examinations, and audio-visual software purchased, with approval, from the Open University in the United Kingdom.

Our pilot study in 1983 gave us some encouragement and, most interestingly, 10 out of the 17 students continued with Science study into Year 2 in 1984, thus committing them to the major study in science in Years 3 and 4. Given that three students failed, 10 out of 14 is a far higher retention rate than anything we have experienced previously.

Clearly, the evaluation of our efforts to influence the teaching of science in Tasmanian primary schools must wait, but these evaluative studies should make a contribution to the research data on curriculum issues in Australia.

This course could play an important in-service function for present primary teachers. We are hopeful that such a content-based approach to science teacher education may help to convince teachers to take the extensive range of available curriculum materials seriously.

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CURRICULUM DEVELOPMENT IN SCIENCE BY MASTER'S AND Ph.D. STUDENTS

Pinchas Tamir

Prior to the curriculum reform of the 1960's most curriculum materials were prepared by single authors and the student textbook had been the exclusive form used by curriculum authors. Since the 1960s the principle of team work and deliberation among subject matter specialists, teachers and other experts such as philosophers, psychologists, and sociologists became the dominant model in the curriculum literature (Tyler, 1949; Grobman, 1969; Schwab, 1971). However, in practice, a variety of 'naturalistic' curriculum development models have emerged (e.g., Grobman, 1970; Reid & Walker, 1975; Shipman, 1974; Walker, 1971).

The focus of the present paper is on a curriculum development model which has received hardly any attention in the curriculum literature, but which, nevertheless, has been around for quite some time and which is gaining momentum especially in science and mathematics education in several countries. We refer here to curriculum development as a topic of Ph.D. and Masters' dissertations. Such dissertations are designated as 'curriculum development dissertations'. To qualify as a 'curriculum development dissertation' the thesis should include actual development of at least one unit of curriculum materials.

More specifically our purposes are:

1 To estimate the relative frequency of curriculum development dissertations, especially in science and mathematics, in selected countries.

2 To identify the topics and issues featured by curriculum development dissertations and estimate their relative frequency.

3 To identify and discuss the merits and limitations of dissertations as far as curriculum development is concerned.

4 To describe briefly the conditions which promote the high emphasis on curriculum development dissertations in science and mathematics in Israel and the actual contribution of some of these dissertations in schools.

METHOD

The data pertain to six countries, namely: Australia, Federal Republic of Germany, German Democratic Republic, Israel, United Kingdom, and the United States of America. Three analyses were undertaken:

1 Calculating the relative frequency of curriculum development dissertations in each country.

2 Classifying the curriculum development dissertations into categories, based on their titles.

3 Calculating the relative frequency of dissertations in each category.

FINDINGS

Relative Frequency of Curriculum Development Dissertations

Table I summarizes the data about the number of Ph.D. and Master's dissertations and the percentage of curriculum development dissertations (see bottom line in the Table) which were included for comparison purposes, the rest of the data pertain to science and mathematics. No data about Master's theses either in the two Germanies or in the U.S.A. were available.

The most striking result in Table I is the extremely low percentage of curriculum development dissertations in science and mathematics in Australia, the U.K. and the U.S.A. contrasted with the very high percentage of such dissertations in Israel. Interestingly in both Germanies the relative frequency of curriculum development dissertations is considerably higher than in the English speaking countries. Another point of interest is the higher percentage of curriculum development in the general curriculum field compared with science and mathematics in the U.S.A. It may be concluded that dissertation supervisors in English speaking countries tend to discourage curriculum development, while in Israel the opposite situation prevails.

Topics and Issues Featured by Curriculum Development Dissertations

The data in Table II was obtained by examination of the titles of the dissertations as presented in the sources listed in Table I. The following categories were used:

1 A new topic developed for the university level. For example: The development and evaluation of a comprehensive first semester college jazz improvisation curriculum', or 'A mathematics core curriculum for forestry and technology in the two year college'.

2 A new topic developed for the high school level. For example: 'The development and evaluation of a geological unit for Maine to be used in eighth grade science classes', or 'Physics in medical diagnosis: A new physics unit for high school'.

Table I

The yield of science and mathematics dissertations in selected countries and the frequency of curriculum development among them

Country	Years	Discipline and Source (in brackets)	Ph.D. N	Ph.D. % curriculum development	Master's N	Master's % curriculum development	Source
Australia	1974-79	Science	13	0	50	6	Layton (1980)
Federal Republic of Germany	1970-80	Science	78	30	--	--	Newting et al (1983)
German Democratic Republic	1970-80	Science	202	23	--	--	Newting et al (1983)
Israel, Jerusalem	1970-83	Science	16	68	36	25	Mendoza et al (1984)
		Mathematics	6	50	8	13	Mendoza et al (1984)
Israel, Rehovot	1976-82	Science	9	66	8	0	Bruckheimer (1982)
		Mathematics	2	0	5	40	Bruckheimer (1982)
United Kingdom	1970-80	Science	88	5	--	--	Newting et al (1983)
	1976-82	Science	65	3	527	2	Layton (1979, 1981, 1983)
		Mathematics	12	0	118	2	Layton (1979, 1981. 1983)
United States	1970, 75, 80	Science	168	5	--	--	Newting et al (1983)
	1980, 83	Science	135	2	--	--	Dissertation Abstracts (1980,83)
		Mathematics	118	3	--	--	
		Curriculum	181	12	--	--	

-- not available

Table II

Frequency distribution of curriculum development dissertations by categories in selected countries

Country	Type		N	Frequency in each category*					
				1	2	3	4	5	6
Australia	Master's	Science	3	0	1	2	0	0	0
Federal Republic of Germany	Ph.D.	Science	24	2	6	7	3	4	2
German Democratic Republic	Ph.D.	Science	46	1	13	12	7	10	3
Israel, Jerusalem	Ph.D.	Science	11	0	3	2	2	3	1
	Master's	Science	9	1	3	1	4	0	0
	Ph.D.	Mathematics	3	0	0	1	2	0	0
	Master's	Mathematics	1	0	0	1	0	0	0
Israel, Rehovot	Ph.D.	Science	6	0	4	1	0	0	1
	Master's	Mathematics	2	0	2	0	0	0	0
United Kingdom	Ph.D.	Science	6	3	3	0	0	0	0
	Master's	Science	10	1	5	3	0	0	1
	Master's	Mathematics	2	0	1	0	0	0	1
United States	Science	Ph.D.	11	8	2	1	0	0	0
	Mathematics	Ph.D.	3	2	0	0	0	0	1
	Curriculum	Ph.D.	21	9	6	5	0	0	1

*1 = A new topic, university level

2 = A new topic, high school level

3 = Innovative instructional strategy

4 = Combination of new topic and new strategy

5 = Teaching difficult concepts

5 = Teaching special student populations

3 An innovative instructional strategy. For example: 'A creativity oriented physics curriculum for secondary schools', or 'A practical method of teaching shape and area to children 7/8 years using a multiple embodiment approach'.

4 Combination of new topic and new strategy. For example: 'A unit on plant identification for individualized learning', or 'Teaching colorimetric methods by the audio-tutorial approach'.

5 Teaching difficult concepts. For example: 'The development and evaluation of a unit on basic concepts of scientific research', or 'The development and evaluation of a lesson sequence to teach high school students to distinguish between causal and teleological explanations'.

6 Teaching special student populations. For example: 'Teaching biology to heterogeneous 7th grade classes', or 'Development implementation and evaluation of a biochemistry curriculum for nursing schools'.

Examination of Table II reveals that categories 1, 2, and 3 are most popular while categories 5 and 6 are the least popular. However, closer examination will reveal considerable differences between different countries. For example, while 70 per cent of the U.S.A. science and mathematics dissertations developed curriculum materials for the college level, only one out of 32 dissertations in Israel (3%) was aimed at the college level. Categories 3 and 4 were found in Israel considerably more than in other countries, and category 5 was found only in Israel and in the two Germanies.

That very few such dissertations were carried out in the U.S.A. may reflect the fact that very few university professors in this country have been directly involved in curriculum development, as well as the temporary nature of curriculum development projects in the U.S.A. which does not enable systematic long term interactions with graduate students.

Limitations and Merits of Curriculum Development Dissertations

The fact that in many countries curriculum development dissertations are so rare is probably a result of their unique nature. As already mentioned in the Introduction, modern models of curriculum development stress the importance of team work and deliberation among experts of varied skills. This kind of team work is not compatible with the nature of dissertations which are supposed to be a creation of one person. Furthermore, the time period required for development, trials, and revision is usually longer than that commonly devoted to dissertations. Consequently the scope of curriculum development within dissertations must be limited. Our experience shows that a unit of up to five lessons for a Master's thesis and of no more than 15 lessons for a Ph.D. thesis is all that can be expected if reasonable standards are to be maintained. The only way to develop a whole course, say for one year of study, is by

the supervisor undertaking the role of co-ordinator and assigning portions of the curriculum to different students. An example of this is the audio-tutorial science curriculum for Grades 1 and 2 which was designed by Novak and his students in Cornell between 1967 and 1975 (see Novak 1977, pp.238-44).

It may be concluded that any one curriculum development dissertation can either deal with a specific well-defined issue, such as identifying a plant with the aid of a key of distinguishing between causal and teleological explanations, or else be part of a series which together will constitute a broader curriculum for an entire course.

While the limitations mentioned above, and perhaps others which may exist, should be borne in mind, the curriculum development dissertation was found to have considerable merits, some of which are listed below:

(a) It is closely supervised and assessed by a number of independent experts, a procedure which guarantees quality control.

(b) The product of the dissertation is not 'shelved' like in many other kinds of dissertation, but instead, is readily applied and makes a direct contribution to the educational practice. This makes the students feel good about the usefulness of their efforts.

(c) In countries where budgets are tight and expertise scarce, curriculum development dissertations constitute an inexpensive way of producing innovative units as well as making good use of the expertise of the supervisors and other university experts.

(d) Curriculum development dissertations are especially effective for pilot trials of innovative strategies, for developing units about topics which are new to the school curriculum and for the design of units aimed at enhancing the understanding of difficult concepts and overcoming students' misconceptions.

(e) Units developed within dissertations can often serve for additional research purposes, such as testing the validity of a learning theory, or analyzing students' preconceptions.

Curriculum Development Dissertations in Israel

Table I clearly shows that a very high proportion of the science and mathematics dissertations in Israel have involved curriculum development. How can this be explained?

In the early 1960s, following the curriculum reform in the U.S.A. and in the U.K., a number of curriculum development projects in science and mathematics were established in the two leading institutions of higher education, namely, the Hebrew University and the Weizmann Institute of Science. These projects were initiated and directed by leading scientists who recruited experienced teachers and Ministry

inspectors as collaborators. While enthusiasm was high and the needs for courses' improvement were very urgent, expertise in modern curriculum development was practically nil. Hence, most of the high school programs in that early period were adaptations of programs developed in the U.S.A. and to some extent in the U.K. However, it was quickly realized that in order to better meet the local needs, future curriculum development should be done locally and, hence, there was a great need for people to gain expertise in curriculum development as well as in other aspects of science and mathematics education. As a result two science teaching departments, one at the Hebrew University and the other at the Weizmann Institute of Science were founded in the late 1960s. These departments were designed to achieve two main goals: (a) to promote research in science education, and (b) to train researchers and leaders in the field of science education. Many of the scientists who volunteered their services to the work of curriculum development found themselves in the position of dissertation supervisors. Naturally, these kind of supervisors in such a mileau favoured dissertation topics which were closely related to the problems in their everyday work in curriculum development. Typical examples of such topics are: 'The teaching of biology in mixed ability classes', 'A field study unit on desert ecology', 'A curriculum on human biology for Grades 7 to 9', 'A human biology module using a holistic approach', 'A new algebra curriculum', 'Teaching topology in high school', 'Substituting laboratory work in chemistry by filmed experiments', 'A geo-chemistry curriculum for high school students'.

Later on in the mid-1970s a 'new' generation of supervisors emerged. While the first generation consisted of supervisors whose own research was in science and mathematics proper, the new generation comprised professional science educators, namely persons with Ph.D. degrees in science education whose own research was in science education.

Although close contact with curriculum development has been maintained the nature of the supervised dissertations has changed.

Two major types may be identified. In the first, a unit is developed in such a way that it provides opportunity to test an innovative instructional approach. For example: 'Teaching microbiology with the help of concept mapping' or 'A teaching game for elementary chemistry' or 'Hormonal communication: an integrated biology chemistry unit', or 'Teaching evolution by historical approach'. In the second, the dissertation consists of two parts. The student begins by an analytical-diagnostic study of a certain issue, e.g., 'learning difficulties in the laboratory' or 'the ability to distinguish between teleological and causal explanations'. Having identified a problem, or a set of problems, specific remedial curriculum units are then developed,

tried and evaluated to find out to what extent has the remedy been successful. The 'new' generation of dissertations often incorporates ideas and concepts borrowed from the history and philosophy of science.

The products of curriculum development dissertations have a relatively high potential of being actually used in educational practice. Indeed, all the units so developed at the two science teaching departments in Israel have been revised on the basis of their formative evaluation and in their revised form are currently being used in schools. Thus curriculum development dissertations appeasr to be a viable and useful alternative model for curriculum development, especially for units of limited scope featuring innovative approaches and focussing on particular instructional and learning problems.

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SO YOU THINK THE GUIDE MATERIALS LOOK GOOD!

Ken Appleton, Eleanor Hawe, Fred Biddulph, and Roger Osborne

INTRODUCTION

> What goes into persuading a body of teachers to think about trying new ideas? Can such ideas and curriculum practices be communicated using written materials alone? These are hard questions - but they are important ones, if only because written materials represent, when contrasted to in-service courses, workshops, and the like, a potentially most cost-effective way of influencing teachers. (Westbury, 1983 : 2)

In the work of the Learning in Science Project (Primary) the issues outlined by Westbury (1983) were a major influence in determining how teacher change might first be attempted by the Project team. On the basis of earlier studies (Biddulph & Roger, 1983; Biddulph & McMinn, 1983) a draft teachers' guide booklet was produced (Biddulph & Osborne, 1984). This provided the broad outline of a different approach to primary science (Biddulph, Osborne & Freyberg, 1983) together with an appendix of illustrative suggestions related to the topic 'Floating and Sinking'. This booklet (Booklet 1) was designed for the experienced confident teacher who might prefer a guide which outlined the key issues of the approach but which left the details to the teacher. A second teachers' guide, Booklet 2, attempted to support teachers who might require much more specific suggestions for classroom teaching and learning on the topic of floating and sinking. The booklets were prepared using information about children's ideas on floating and sinking and were revised following theoretical analyses by Symington (1983) and other members of the LISP team.

This paper considers some key issues arising from the first trial of each booklet in the classroom. A full account of the trials is provided in Appleton, Hawe, and Biddulph (1984).

THE TEACHERS AND SETTINGS

The less structured teacher guide, Booklet 1, was trialled by an experienced teacher, and the more structured version, Booklet 2, by a teacher entering her second year of teaching. Both trials were conducted in mixed-ability classes of nine year olds in an urban school. The trials continued over a two-week period early in the school year, and comprised four and six lessons respectively.

EVALUATION METHOD USED

The broad purpose of the evaluation was to gain some idea of both the extent to which the authors of the booklets were able to convey their intentions to the teachers and the problems encountered by the teachers in their teaching. Two observers who had no perceived commitment to the teaching suggestions were present in the classrooms (one in each) throughout the trials.

Following the methodology of Tasker and Osborne (1983), an attempt was made to compare the suggestions of the booklets with the teachers' intentions for instruction and their actual classroom instruction. Field notes of both informal discussions with the teachers and classroom observations of the lessons were kept for this purpose. Tape recorders were not used during the lessons as it was felt that they would constitute a threat to these teachers. Post-trial interviews were also conducted with about ten children from each class, and with the teacher who trialled Booklet 1. All interviews were recorded on audio-tape and later transcribed.

EVALUATION OF THE TRIALS

In some ways the actions of both teachers were consistent with the suggestions in the booklets. For example, the teacher who trialled Booklet 1 attempted to follow the sequence of steps in the suggested teaching approach, and tried to help children find answers to the questions they had asked. The teacher who trialled Booklet 2 attempted most of the activities suggested, and in the order in which they appeared. She also made use of the suggested means of recording the children's responses. The consistencies, however, were mainly at a relatively superficial level.

In other more fundamental ways the lessons taken by both teachers diverged from the intentions of the authors of the guide booklets. These divergences highlighted problems central to the development and use of teacher guide booklets.

Booklet 1 - The Unstructured Version

Booklet 1 outlined a general teaching approach constituting the following steps adapted from Biddulph, Osborne and Freyberg (1983):

STEP 1 Provide your children with experiences that will enable the children to ask questions. Record their questions.

STEP 2 Decide which questions are to be investigated.

STEP 3 Assist the children to plan their investigations.

STEP 4 Provide assistance to the children during their investigations.
STEP 5 Assist the children to record, interpret, and report their findings.
An appendix contained information about children's and scientists' ideas of floating and sinking, together with suggestions for materials and learning situations that could be used with the various steps in the approach.

The teacher attempted to follow the sequence of steps, and was quite successful with Step 1 and Step 2. Although she chose an alternative stimulus to the one suggested in the appendix of the booklet, the children nominated questions which were recorded on the blackboard, and in groups chose three questions for investigation. However, from Step 3 the teacher deviated dramatically from the suggested approach. Instead of having the children plan investigations to test their questions, she provided an unrelated activity which all the children were to undertake. In small groups, the children tested various objects to check their floating/sinking properties, when reported their observations to the class. In the next lesson, the teacher asked each group to make a piece of plasticine float, and think of some reason why it floated.

The children were successful in making the plasticine float, but the few explanations they were able to offer did not seem to the teacher to be satisfactory ones. The teacher then read to the class an explanation of floating from a book (which described Archimedes' Principle), and added her own explanation, telling how the molecules are further apart in floating materials, and how plasticine can be made to float by pushing the molecules further apart!

By diverging from the suggested approach, the teacher prevented the children from planning and hence conducting their own investigations. Consequently the children's ideas were not challenged in the way intended. Why did she diverge from the suggested approach? It seems that several factors influenced her.

(a) <u>She was uncertain about how to help the children plan investigations and carry out their plans</u>. She told the observer this several times, and commented in a similar vein in the post-trial interview (Note 1):

> 'Some children come up with some questions that would never cross your mind and you think: Where do I go from here?'

Her uncertainty was made worse by her own lack of background knowledge of the topic.

'I felt that I needed to know more about the actual topic itself ... I was floundering around trying to find things out ... I was getting a bit desperate ...'

She felt this prevented her from helping the children:

'When the children came up with their questions I couldn't really answer them properly. You know, I couldn't guide them I felt to find their own answers'.

(b) She was uncertain about the approach because it contrasted with her idea of classroom science. She saw science as a subject in which pupils carried out activities which they found enjoyable and from which they induced conclusions.

'I would like to provide some experiments ... have some experiments set up that gave them the answers'.

She felt that Steps 1 and 2 of the approach had delayed activity work too long, and was unwilling to postpone it any longer. Although she knew that the second activity she provided would not answer the children's questions she had hoped that they would arrive at a conclusion for the (to her) important question of why things float.

(c) The approach implied a teacher-role which differed from what she saw as her role in the classroom. The teacher's comments and behaviour indicated that she saw herself as the provider of knowledge for the children, whereas the approach implied that the children should accept greater responsibility for their own learning. She believed she should provide activities from which she hoped the children would obtain her desired answer. It was she who searched for resources for the children to use, but with little success. When all else failed, she resorted to telling the children her answers to her question.

'Really it falls back on the teacher. If the children are desperate, you've got to tell them, haven't you?'

It was clear to the observer that not only the teacher but also the children saw the teacher's role as a provider of knowledge. Children accepted and remembered the molecules answer provided by the teacher; seven of the 11 children interviewed after the lesson invoked some explanation involving molecules to account for floating and sinking.

Booklet 2 - The Structured Version

Booklet 2 contained suggestions for specific investigations and projects that might be undertaken to answer children's questions and challenge their ideas. The booklet contained four investigations basic to ideas about floating and sinking, four extension projects to develop further ideas, and three applications projects putting floating and sinking in a societal context.

Although the teacher who trialled this booklet followed many of its suggestions, she too failed to challenge the children's ideas about floating and sinking. Reasons included:

(a) Managerial issues influenced planning. For example, in the extension project (making non-floating materials like plasticine float and carry cargo) the teacher provided cues as to how to solve the problem before the children started. She also changed the emphasis of the activity so that it became a competition, which made management easier.

> 'We hollowed them [potato and plasticine] out and we had to put marbles in and the group that got the most marbles in without it sinking won the competition, but we didn't get anything for it'. (Child in post-trial interview)

These actions by the teacher seemed to effectively nullify any challenge to children's ideas that was inherent in the activity.

(b) During group work she seemed primarily concerned with management of the groups. Her choice of group size seemed to be determined by pragmatic considerations such as equipment available, and any interaction she had with the groups seemed to deal with only the functions of the group.

(c) She believed children would learn when they are ready. For example, by the end of the first lesson, she decided that there was little she could do to move the children towards the scientific view, apart from telling them the answer. In a later comment the teacher wrote,

> The children, however, once hooked onto an instant solution to a question [to why things float] seemed to develop a mental block and could not be questioned further.

She told the observer that she did not think the children were ready yet to understand such 'abstract notions' as light or heavy for their size. This discussion suggested that because of her belief in a stage theory of development, she did not feel she could influence the children's ideas unless they were at the 'stage' when they were 'ready' for it.

In the post-trial interview, none of the nine children interviewed seemed to have arrived at the desired conclusion that things float because they are light for their size. The responses they gave, such as 'because they are light', or 'have holes in them' suggest that their ideas were not really challanged.

(d) She ignored opportunities that were clearly present to challenge children's ideas. For example, when children reported their findings to the class, she wrote

the first acceptable response on the blackboard without checking how common the finding was, querying its accuracy or searching for implications and conclusions.

ISSUES ARISING FROM THE TRIALS

The two teachers who trialled the guide booklets were not science enthusiasts and were reasonably representative of teachers in New Zealand primary schools. In our view the trials provided a realistic indication of what could happen if such material were given to teachers, and raised a number of issues concerning teacher education and the development and use of guide materials. These issues include:

i) The influence of the teacher's view of science and of learning. Each teacher's classroom actions appeared to be influenced by her own view of science, of science teaching and of how one learns science. One teacher's view was that children should discover ideas for themselves or, failing that, she should give them her perception of the scientists' view. The other teracher saw herself as a manager of group work and she believed that the children were not ready to develop their ideas further. In both classrooms children's ideas were not challenged. These teaching responses have also been noted by Smith and Sendelbach (1982).

ii) The influence of the teachers' guide material on teaching and learning. When teachers' guide material suggests an approach which conflicts with the beliefs and assumptions that underlie classroom practice a range of conflicts and compromises can occur. In this study where the key outline of the approach was provided (Booklet 1), and the details left to the teacher, the teacher deviated completely from the proposal. Where details and suggestions were provided (Booklet 2) the teacher followed the activities suggested superficially but the key features of the teaching approach were neither appreciated nor acted on by the teacher. However neither teacher appeared fully aware of how much her teaching intent and practice differed from that proposed by the authors. This emphasizes the necessity of having observers in the classroom to describe what actually occurs when trial guide materials are used.

iii) The possible influence of teachers' guide material on teacher behaviour. The authors had given considerable thought to, and received advice from, other researchers on the content and presentation of the guide booklets. However the booklets did not generate the teacher behaviours hoped for because the approach was not accepted and the way the 'conceptual change' approach to teaching differs from the 'activity', 'discovery', and 'didactic' approaches was not appreciated. Of course it

is possible that the experience of using the booklets and being involved in this trial may have instigated changes in teacher behaviour which were not apparent during the trials. We are also uncertain as to whether the guide materials alone can promote the conceptual change view of teaching and the consequential changes in teacher actions desired by the authors. While teachers guide materials alone are most cost-effective, the need for interactive communication through in-service courses to support written materials may have to be accepted if the practice of teachers is to be influenced substantially.

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Note 1. The quotations are taken from the post-trial interview with the teacher.

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THE EFFECTS OF AN ACTIVITY-BASED CURRICULUM ON STUDENT OUTCOMES IN CHEMISTRY IN THAILAND

Sunee Klainin

INTRODUCTION

Since the late 1950s, school science curricula have undergone considerable change. Process was stressed: many science educators agreed that science should be taught by an inquiry/discovery approach. This can be seen in major science curriculum projects such as Physical Science Curriculum Study (PSSC, 1964), Biological Science Curriculum Study (BSCS, 1963), Chemical Education Materials Study (CHEM Study, 1963, 1976), in the United States and the Nuffield Science Project (1963) in the United Kingdom. These curricula had set out to shift laboratory work from simply demonstrating or verifying known information to the task of being a method for learning about science and the process of scientific inquiry. Laboratory work, previously separated from normal classroom learning, became an integral part of classwork. It was hoped in this way to provide students with practical skills of manipulation and observation, abilities to raise problems and to solve them. It was also believed to develop higher cognitive abilities in the learners as well as scientific attitudes.

The Chemistry curriculum for the higher secondary school in Thailand was also influenced by these changes. The curriculum prior to 1976 was a traditional one, where theoretical and practical parts were taught separately with little or no relationship. Practical work was used for demonstration or verifying known facts. The 1976 curriculum was a drastic change because it borrowed ideas from curricula that exist elsewhere in the Western work. It was designed as an activity(laboratory)-based curriculum in which laboratory work is integrated with content through the whole course. Laboratory work was not to follow the concept but to lead to the concepts. Inquiry/discovery approach was recommended to teach the courses (UNESCO, 1981).

Although new curricula have stressed practical work as a way to conduct scientific inquiry and learn science there are only a few studies that have tried to check the validity of this role for laboratory work (Atwood, 1967; Hardy, 1971; Tamir, 1972 Raghubir, 1979; Shymansky et al., 1983). 'The research on the relations between laboratory and other learning modes remains scarce' (Shulman & Tamir,

1973). It has been some 25 years since the laboratory-based courses were first introduced and a vast expenditure of time and money has been invested but the question 'how effective were new science curricula in enhancing student performance?' is still unanswered (Shymansky et al., 1983). In Thailand, the 1976 curriculum was revised in 1981. The revised version still has the same characteristics for the place of practical work although the curriculum developers have no evidence for its effectiveness.

The present study was therefore set up to investigate the effectiveness of the new chemistry curriculum in Thailand. It attempted to answer the question, Does the curriculum develop practical skills of manipulation and observation, problem solving skills, scientific attitudes, and higher cognitive abilities?

Variables

The beliefs about what practical work should do for learners were translated into the criterion variables of the study. (See Box 1.)

BOX 1

Variables that are derived by translation of beliefs about practical work

	Beliefs		Variables
1	Develop practical skills	→	manipulative skills
2	Develop observational skills	→	observational skills
3	Develop process of scientific inquiry	→	problem solving skills
4	Enhance in higher cognitive learning	→	cognitive outcomes
5	Promote positive attitudes toward science and science related attitudes	→	scientific attitudes

It is also believed that time is a critical factor for schooling. The amount of time students spend studying academic subjects is important in determining success (Berliner, 1979; Johnson & Butts, 1983; Bloom 1976; Lahaderne, 1968). Therefore, one independent variable of the present study is the time students spent studying the course.

The study also set out to look into the impact of the course on boys' and girls' learning of science. Thus, another independent variable is students' gender.

RESEARCH DESIGN

Sample

A study of high school chemistry students was carried out in six schools in Bangkok. The students were in three grade levels (10, 11, and 12) of higher secondary schools. Grade 10 spent one year studying the activity course, while Grades 11 and 12 spent two and three years respectively. Two classes were studied at each grade level in each school, i.e., there were 12 classes at each level. There were 510 students (252 males) in Grade 10, 475 students (217 males) in Grade 11, and 496 students (245 males) in Grade 12.

There were three types of schools among the six schools. There were two boys' schools, two girls' schools, and two co-educational schools.

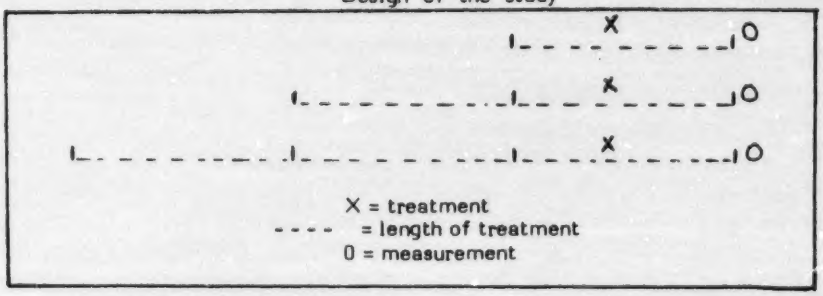
Design of Experiment

A simulated longitudinal study was carried out; students at the various grade levels were assumed to be equivalent except for the time they had spent studying the course. In Thailand, almost all students beginning chemistry in higher secondary schools will continue through to Year 12 with this subject.

The design is presented diagramatically (Box 2).

BOX 2

Design of the study



Instruments

The outcome variables were translated into instruments. These are summarised in Box 3.

Box 3.

VARIABLES	INSTRUMENTS	TYPE OF INSTRUMENTS
1. Manipulative skills	Test for manipulative skills	Actual practical exercise
2. Observational skills	Observational test	Practical test comprises - colour changes - temperature changes - gas evolves - precipitation
3. Problem solving skills	Problem solving test	Solving a practical chemistry problem in laboratory
4. Cognitive outcomes	1. Achievement in chemistry test	Multiple choice (30 item)
	2. Test for laboratory work and knowledge relationship	Matching of activities with knowledge bits
	3. Test for types of evidence preferred by students	Multiple choice among - text book - teacher's word - general acceptance/facts - laboratory evidence
5. Scientific attitudes	Test of scientific attitudes	Koxlow and Nay's test of scientific attitudes.

The instruments were constructed by the investigator, except for the test of scientific attitudes. Kozlow and Nay's (1976) Test of Scientific Attitudes (TOSA) was used for this purpose.

The tests of manipulative skills were an adaptation of Kempa's type of instrument. The criteria proposed by Eglen and Kempa (1974) was used as reference standards for assessing practical skills. The test required students to perform an experimental exercise according to a well-defined instruction. The assessment was done by direct observation by the investigator and two assistants. Students' performances were assessed with the aid of a check list scored according to a marking scheme. Students in the three levels were assigned the same task. Due to the limited number of assessors, only half the students in each class were assessed.

The measurement of practical skills was complicated. Three observers were required and they had to have the same criteria. At the beginning of the data collecting, the observers were trained in the procedure to be used in recording student performance. Criteria of what to observe, together with a marking scheme and a checklist were given to them beforehand. For practice, three groups of students performed an experiment and the observers recorded what they saw on a checklist and scored each group. The students' actions were video-taped. The observers then discussed discrepancies, came back to see the video-tape, picked up the point where disagreement was found and revised their scores, until a high degree of agreement was attained.

The scoring of the observational test was based on written evidence provided by the students. The scoring of the problem solving test was based on direct observation and written evidence.

The Achievement in Chemistry Test (ACT) originally contained 45 items, from which 30 items were selected after the first pilot testing was done. A second pilot testing was carried out. The KR - 21 co-efficient of reliability of the first pilot test is 0.65 and the second is 0.60.

Data collection was carried out from May 1983 to March 1984.

RESULTS

A preliminary analysis of the data has been made using SPSS Breakdown, Analysis of Variance and Scheffe Range Test. Results obtained at this stage suggested the following findings :

1. Manipulative Skills

The mean scores of the manipulative skills test are shown in the graph in Figure 1. Manipulative mean score increased from Grade 10 to Grade 11, but it decreased in Grade 12. One way Analysis of Variance yielded significant difference (at 0.01 level). Scheffe Multiple Range Test suggested that the differences were significant between Grade 10 and Grade 11, between Grade 10 and 12, but the differences between Grade 11 and Grade 12 were not significant.

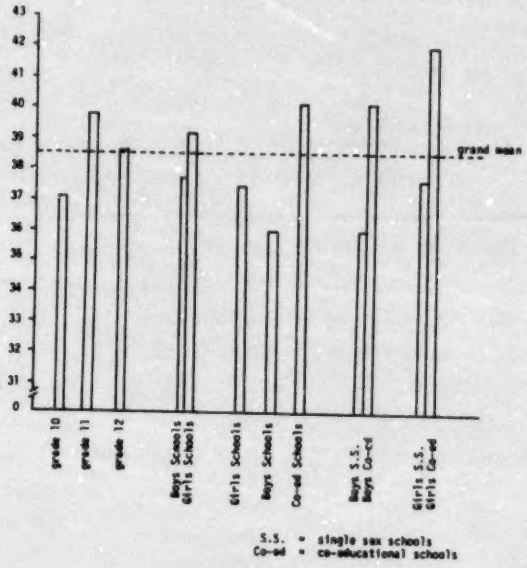


FIGURE 1 Mean Scores of the Manipulative Skills Test

Girls performed better ($p < .01$) than boys and the differences were significant. Students in co-ed schools performed better ($p < .01$) than students in single-sex schools; this finding applies to both males and females.

2. Observational Skills

Students' mean scores on the observational skills test did increase with the higher grade level, but not significantly. Girls performed significantly better than boys. The co-ed girls performed significantly differently from the boys both in the co-ed schools and single-sex schools and from the girls in single-sex schools.

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3. Problem-solving Skill

An area of prime importance in teaching science is that of problem solving (Gabel, Sherwood, & Enochs, 1983). The students in this study were found to acquire better skills as they spent more time studying the course. That is, Grade 12 students performed better on this test than Grade 11, and Grade 11 performed better than Grade 10. The differences were significant.

Girls also performed significantly better than boys on this test. However, the differences between boys and girls in single sex schools were not significant. In the co-educational schools, however, girls performed significantly better than boys.

4. Achievement Test

The mean scores on the achievement test gave the expected results: scores increased significantly as students spent more time studying the course.

Although girls performed better than boys on this test the differences were not significant. However, the multiple range test showed that the girls in single sex schools who had the highest mean scores were significantly different from the boys in co-educational schools. The differences among the other groups were not significant.

5. Test for Type of Evidence

The same trend as for the manipulative skills test was found in the Test for Type of Evidence. In this test, students were asked to choose among four possible types of evidence (text books, teacher's word, laboratory work, and general acceptance or facts) as a basis for their concepts in chemistry. Most students chose to use laboratory work as their source of evidence. This preference was highest in Grade 11; Grade 12 was in the middle and Grade 10 was lowest.

6. Scientific Attitudes

Preliminary results suggest that scientific attitudes increased significantly from the lower to higher grade levels.

Girls displayed significantly more favourable attitudes than boys. Girls in single-sex schools performed better than the other groups; the multiple range test showed this group to be significantly different from boys in single-sex and co-ed schools, but the difference from girls in co-ed schools was not significant.

CONCLUSION AND DISCUSSION

The trends for two variables in this study, namely manipulative skills and preference for laboratory evidence, an increase from Grade 10 to Grade 11 and a decrease in Grade 12, were not consistent with the trends of other variables. This is not necessarily due to the effect of the curriculum itself. One major fact that may account for this effect is the national tertiary entrance examination in Thailand. All students who want to study in universities after they have graduated from high school must pass this examination. The examination is based only on content and theoretical knowledge. This could be the major cause that turns Grade 12 students to emphasise the study of content only. They try to avoid practical work because they do not see its immediate importance.

Apart from these two variables, the other results suggest that the laboratory/discovery-based curriculum has been successful. Students have shown increasing scores from lower to higher grades. These learning variables were stated in the course objectives: observing carefully, formulating hypotheses, designing and executing investigations, recording data, analysing and interpreting data, forming conclusions or generalizations, and acquiring content matter of the subjects.

Scores on tests of scientific attitudes (critical mindedness, suspend judgement, respect for evidence, objectivity, open-mindedness, questioning attitudes, willingness to change opinion, and honesty) suggest that these do develop over time: higher scores are associated with later grade levels.

Another finding of interest is that girls' performances in every variable of this study were better than that of boys. This finding is opposite to those found elsewhere (Stein & Bailey, 1973; Comber & Keeves, 1973; Gardner, 1974, 1984; Hofstein et al., 1977; Whitfield, 1979; Ormerod, 1981; and Vockel et al., 1981).

The only finding in favour of girls that has been found elsewhere was in observational skills. Hofstein et al.'s explanation of this was that the test involved many colour changes and that colour defects in women were very rare as compared to men. This explanation may also be an influence in the finding of the present study. However, the other strong findings in favour of girls need different explanations that are not yet available. Some further studies may be needed to investigate whether the courses in Thailand favour girls more than boys.

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SCIENCE CURRICULA FOR ADAPTIVE SCHOOLS: A REPORT FROM THE WORKFACE

Julia Atkin

INTRODUCTION

Over the past five years in Australia and elsewhere there have been many calls for reform of secondary school curricula - especially for the junior years. A number of the reports and papers on reform have been prepared by academics, the Schools Commission, and other professional educators. There have been many attempts by the educational 'practitioner' to trial alternative approaches to curriculum, the teaching/learning situation, assessment and school organisation. Much of this work is not documented in the regular research journals but descriptions can be found in the writings of Middleton (1982), Pettit (1980), O'Carroll and Berryman (Note 1), Atkin and Jamieson (Note 2), Boomer (1982), and in the work of many schools which have undergone curriculum development projects but whose efforts have not been documented for dissemination.

The purpose of this paper is to present a case study report of curriculum development in science at St Columba's High School, Harden, New South Wales during 1982-84. Science curriculum development at St Columba's ultimately did not occur in isolation from development of the total school curriculum. A more detailed account of the total curriculum development can be found in School Improvement : A case study in curriculum change (Atkin & Jamieson, 1984, Note 2).

The Context

St Columba's High School is a co-educational, 7-10 High School under the direction of the Catholic Education Office of the Archdiocese of Canberra-Goulburn. The student population has fluctuated between 66-67 over the past few years. Harden-Murrumburrah, once known as a 'railway town', is now mainly a service centre for a mixed farming district. The town has a population of approximately 2,100 and serves a surrounding district of some 2,000.

CURRICULUM DEVELOPMENT IN SCIENCE, 1982-1984 - A NARRATIVE ACCOUNT

The School Learning Environment - 1982

The school, in 1982, had the following characteristics :

- a very restricted vision and level of aspiration of students;
- students willing to complete tasks for the sake of a mark but little love of learning, enjoyment or sense of purpose;
- very few electives offered due to use of traditional timetable and year groupings which resulted in extremely small classes for electives;
- few subject programs existed and those that did exist had not been revised for several years - they served as 'pacifiers' for inspectors rather than as a true guide for the teaching/learning process;
- much of the assessment in subjects was based on rote 'regurgitation' despite the fact that the professed aims of the course included conceptual understanding;
- developing individualised programs was difficult because of the lack of resources and the lack of funds to develop resources;
- despite the small class sizes, teaching was difficult because of the incredible range of abilities and readiness of students in each year group.

Identification of the Need for Curriculum Change

Having come from teaching in a school where the motivation to succeed, for most students, was high, I took up the role of sole science teacher at St Columba's embued with a sense of confidence that rural youth could be stimulated to approach school and learning in science as having intrinsic 'reward' for them. This naive assumption was based on a belief that, by making my science teaching 'relevant and meaningful' to them, I could lead them to share my enthusiasm for science knowledge. In retrospect, I approached the task with 'naivety and arrogance'.

I believe that my basic error lay in my understanding of what it meant to be 'meaningful'. My approach to making science topics meaningful was to demonstrate, and have the student participate in, activities that were 'real life' examples of the concepts and principles that I was attempting to teach. For example, a Year 10 unit on Linear Motion involved practical involvement of students in motor bike and car trials - comparing acceleration/pick-up, gear ratios/power etc. The students learned a lot (not least of which was their relative personal performance as potential Jack Brabhams) and they were definitely motivated to take part. However, I did not succeed in making more disciplined science knowledge and understanding of the laws of motion come alive for students - the learning outcomes were not the intended learning outcomes, at least not for the majority of the students.

In a teaching circumstance such as this, one is faced with two options for 'survival' and continued 'sanity'. Having faced the fact that not all students are, nor will be, interested in science knowledge for knowledge's sake (that there really is only a 'fascinated few' as Fensham (1983) notes) the options are to use whatever control measures available to the classroom teacher to encourage or even enforce students to

complete learning tasks and hope that they take something away that they may be able to relate back to if the reason arises, OR, to rethink some of the premises on which one bases one's approach to the curriculum and what it may mean for something to be 'meaningful' to the non-fascinated majority. I chose the second option.

Half way through the first term I embarked on an 'action research' project in an attempt to work out what school science should or could be. With the Year 10 class I made a decision to trial, for half a term, a 'negotiated' curriculum. Whether this was to be an ongoing project for the remainder of the year would depend on the success of the trial. When asked what they did want to learn that they thought may have something to do with science, I was met with the following responses:

- Learning how to dye wool using native plants.
- Guns.
- Explosives.
- Car and motor bike mechanics.
- 'How come I've got my mother's webbed toes?'
- Kangaroos and wallabies.
- Astronomy.
- How to repair electrical appliances.
- Boomerangs.
- Energy and its uses like nuclear power and bombs.
- Breeding and butchering of sheep and cattle.

Following the identification of these areas of study which were meaningful to the students, the students and I negotiated what their study program for the area of their choice would be. Some students chose to work in small groups while others chose to work independently. There was certainly no lack of enthusiasm on the part of the students but I felt a degree of uncertainty and fear as I questioned whether I could justify this approach, and as I let go of direct control over the learning situation.

In retrospect, I can see with clarity the power of the approach. Instead of asking 'What in science is it important to teach these students and how can I relate it to their world through "real-life" examples?' I was asking 'What do these students want to learn about life and how can science knowledge enrich their understanding of it?'.

As I was unable to provide all of the resources necessary myself either from my own 'know-how' or school or personal library, students were required to obtain the necessary additional resources themselves. For example, the group of students studying guns brought in a local 'expert' to teach them about safety aspects of

firearms, the student studying kangaroos and wallabies started a dialogue with a CSIRO research scientist working on kangaroos and subsequently spent most of her time working directly from primary sources while the student studying astronomy sought contact with a local group of amateur astronomers for 'stargazing' activities using their equipment.

At that time the organisation of students in the school did not permit the science students across Year 7-10 being able to choose to join in these areas of study. So within one Year 10 class there were five or more different areas of study being undertaken at one time. Logistically and practically this is not a desirable state! The workload for the teacher is massive and it is difficult to be assisting in the tune-up of a motor vehicle at the same time as offering a helping or guiding hand to a group of budding electricians. Thus, it can be seen how strongly traditional school structures mitigate against such curriculum experiments. St Columba's is a small school with a readily identifiable community to provide support and still the mechanics of working such a project within one class group are fairly unwieldly. Despite these concerns the project was a definite success in that students were enjoying learning and they were learning that science knowledge could enrich their lives - knowledge began to touch their lives, it began to work for them.

Two student case studies help to illustrate the varying ways in which this project affected the students' learning and learning of science.

David and John undertook to study electrical appliances after they had finished their study of guns. These two students differed in their abilities to master school tasks in Maths and Science but were similar in that school did 'not offer them much' - in their words. Their work could be characterised as 'scatty' and lacking in perseverance if the task was perceived as difficult. After some initial easy tasks such as electrical radiator repair and the making of extension cords, they undertook to repair an old malfunctioning twin tub washing machine. The task required re-wiring and a diagnosing of a specific problem associated with the switch mechanism in the lid. These two students did not approach the task with sufficient order for them to be able to reconstruct the wiring they had dismantled, and soon gave up. The problem was not entirely theirs as guidance from me was often lacking at crucial moments due to my involvement with the many other tasks going on. Following this episode David and John returned to work on more straightforward jobs and did build up a certain level of skill with regard to minor repair jobs. Ultimately their interest turned to electronic gadgets and they spent a considerable amount of time building electronic devices through the use of electronic project kits. They did not really find a need to 'know' more about how or why electrical devices worked other than a

qualitative understanding of current, resistance, voltage, and series and parallel circuits.

John O could be described as an average student in Science and Maths. Through his study of car mechanics (the negotiated study program involved an understanding of the functioning of the various parts and the interrelationship of the various systems as well as practical tune-up skills) John started to ask why a coil built up voltage and why a condenser was necessary and whether a generator on a bike was similar to a car alternator. His aroused interest led him into a more thorough study of electric and magnetic fields and he went on to study car mechanics at the local TAFE college.

The project continued throughout the year with the Year 10 class. Not all aspects could be called a success nor could it be said that this approach brought about a revolution of interest in the students towards disciplined science knowledge. However, there is no doubt that the knowledge and skills gained by the students were useful to them whether it be at the level of everyday use or whether it be at the level of an increased understanding of disciplined science knowledge. The above case studies tend to understate the extent of the knowledge component in the negotiated program. There was a knowledge component in each program but the depth of understanding required differed from area to area. The knowledge related to the skills or the functioning of the object of study and the knowledge was science knowledge in the sense that it went past a common-sense explanation of phenomena but it was specifically related to the area of study in question and the emphasis was not on the generalizability of the knowledge as tends to be the case with science knowledge in traditional science courses.

As a result of this curriculum experiment in Year 10 Science, the staff became interested in review of the total curriculum with a view to making the school program more 'meaningful, relevant and enjoyable' for the students. The ensuring process of curriculum development and change is described elsewhere (Note 2). The outcomes of this were changes to the organisational structure of the school - vertical age grouping of students in Years 8-10, a line timetable and term length courses - and changes in attitude towards the content of courses; what it means for a course to be meaningful to the majority of students, and to the role of the teacher in the learning situation.

THE ADAPTIVE SCHOOL STRUCTURE AND APPROACH

The present structure of St Columba's program and day can be described as an 'adaptive' structure in which, beyond the minimum curriculum defined by the school, the students are free to progress in the direction of their choosing whether it be

'academic', 'cultural' or 'life skills'. Students follow individualized curricula by choosing courses in various areas of study - courses which suit their level of readiness, their interests and their abilities. Their choices are guided by their parents and their conferencing teachers. Their overall program of study must satisfy New South Wales School Certificate rules and St Columba's prescriptions regarding the school's minimum curriculum.

Courses are offered on a line timetable. Efforts are made, where possible, to integrate across subject areas thus eliminating a lot of the overlap that can occur between subject areas. Attempts are made to ensure 'meaningfulness' of the courses to the students by requesting input from them on the content of the courses. As with the early science project, the approach is to ask 'What in life do students wish to learn about and how can subject knowledge be brought to bear on this topic to enrich it and increase the student's understanding?' Response to students' interests alone could lead to a short sighted view of what may be worth learning and so staff and parental input plays an important part in course development. This approach invariably leads to integration across traditional subject boundaries.

A few examples of the courses which have been offered in science under the new structure are:

'Kitchen Chemistry'	an integrated course in Science/Home Science (students were able to credit this towards Science or Home Science according to their interests in other courses) which involved studies of cleansing and leavening agents, making home made products, comparing commercial brands, the best buy, etc.
'The Outlook for Tomorrow'	Science/Geography, Studies in ecology and the environment - conservation versus exploitation as well as studies of pollution and the weather.
'The Tree of Mankind'	heredity, evolution, basic genetics. A fairly academic course with an orientation towards those students proceeding to Year 11.
'Bones'n Stuff'	the preparation and rebuilding of skeletons from animal specimens. Related studies of evidence for evolution through a study of skeletons for those interested.
'The Human Machine'	a study of the various body systems with the emphasis being on an understanding that enables the student to evaluate 'healthy' and 'unhealthy' habits of eating, exercise, smoking, and to understand common diseases and their causes.

Courses are continually being developed for the coming term and in time a 'repertoire' of courses will be developed.

In developing the science curriculum offerings some guidelines and criteria for courses had to be established. The GOAL and general aims of the science program were reworked and criteria were established for the suitability of courses. The criteria were as follows. A course must be:

- immediately relevant to the students;
- relate to the students' world and build from there;
- enjoyable and satisfying;
- contain a thread of usefulness, and
- provide opportunities for the students to express themselves and to succeed.

It must be shown how courses relate to any or all of the facets of St Columba's minimum curriculum, which specifies experiences in the following areas: Living Skills, Communication Skills; Self Expression; Social Skills and Attitudes; Knowledge and Understanding. It must be shown how the body of knowledge commonly identified as science knowledge relates to the course and it must be shown how the course is in harmony with the State syllabus in science.

CONCLUDING COMMENTS

An an 'action research' project, science curriculum development at St Columba's is ongoing as is the total school curriculum development. An outline of the development in science has been presented here to: invite comment from science educators in order to help define future directions in curriculum development; to stimulate further research in the area of curriculum development for a 'Science for All', and to stimulate debate about what school science, especially junior secondary science, should be.

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Research in Science Education, 1984, 14, 230-231

RESEARCH NOTES

At the Annual Conference a number of informal sessions were organised during which members discussed embryo projects or shared ideas about possible future research and development in science education. The following notes have been compiled from the conference abstracts as an addition to the preceding conference papers so that R.I.S.E. readers will gain a more comprehensive picture of the matters that were raised during the conference.

1 Pupils' views about crystals by Brendan Schollum

This session reported on the progress of a study designed to examine the objectives, teaching, and learning associated with the common junior activity of crystal growing. Some preliminary findings about pupils' ideas about crystals, how they form and where they originate were presented. Pairs of the twenty 13 and 14 year olds who participated were also observed (and questioned) as they attempted to follow instructions on how to make crystals: some details of these observations were also presented and some discussion occurred on future directions for the project.

2 Review of teacher education in primary science by J. Owen, N. Johnson, and R. Welsh

In this progress report the authors outlined what they had done to date in their study of the state of teacher education in primary science during 1984. The project involves the collection and the dissemination of information which the authors hope will lead to improvements in the teaching of science in primary schools.

3 The science curriculum and the student science laboratory by Elizabeth Hegarty

A curriculum model was presented showing the role of laboratory work in the educational process in a science discipline. The model was regarded as an attempt to extend ones dsaigned by Johnson, Stake, Saylor and Alexander, and Harnischfeger and Wiley.

4 Developments in the use of interactive videodisc in the teaching of science by G.W. Dettrick

Recent developments in the use of laser videodisc technology were presented and the Tacoma Narrows videodisc was demonstrated. Details of the Annenberg project were also outlined together with the value of the medium for in-service education of science teachers.

5 Science teaching action research project (STAR project) by Effie Best

A progress report on what teachers have been doing in the project was presented. Four researchers and advisers are collaborating with eight enthusiastic, competent science teachers on ways to observe one's teaching, to interview pupils and to document obervations and interviews. The teachers are trying out teaching strategies designed to change students' beliefs about the world.

6 Laboratory technicians and laboratory safety by John Gipps

Several issues about the role and training of laboratory technicians were discussed. It was suggested that

(a) subject associations could help with the training of technicians;

(b) science co-ordinators should facilitate the training of laboratory technicians, and

(c) appropriately trained laboratory technicians should be concerned with safe storage of materials, security of science laboratories, the testing of demonstrations for safety, assistance to teachers during laboratory lessons, and advice about safety measures to less experienced teachers.

7 Problem solving in chemistry : determining variables and difficulties in teaching and learning by Kam Wah Lee

This session consisted of a progress report on research concerning problem solving in chemistry (electrochemistry in particular). In the project an attempt is made to identify variables responsible for problem solving behaviour and to develop a model of problem solving strategy. One part of the study explores the model quantitatively and another investigates the difficulties of teaching and learning problem solving in chemistry.

8 The effects of an environmental field study program on the environmental attitudes of Grade 6 students by Dave Burton and John Edwards

This session was a report on the affective changes in 67 Grade 6 students who attended a three-day live-in environmental field studies program. An environmental attitude scale developed for the study was administered to the 67 students and to a control group of 42 students. The results suggested that the program had an effect on some areas of students' attitudes.

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The following requirements have been established to facilitate editing, maintain standards in format and presentation and ensure that as many as possible of the conference papers can be published in RISE.

GENERAL LAY-OUT AND LENGTH

Setting out: The paper (including diagrams, tables, etc.) is to be typed on A4 sized paper, using double-spacing with wide margins - at least 2.5 cms on the left and 1.4 cms on the right. (Note that these margins are to be left on all pages, including those containing tables, diagrams, etc.)

Length: The total length of any one paper must not exceed twelve A4 double-spaced typed pages (this length includes text of the paper, reference lists, and all diagrams, figures, and tables).

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FOOTNOTES AND REFERENCES

Footnotes: These should not be used although Reference Notes, e.g., Smith (Note 1) may be used to refer to unpublished material. The reference notes are to be collated at the end of the paper, e.g.,

Note 1, J.J. Smith, personal communication

Note 2, R.E. Jones, 'Myths about science teaching', paper presented at the Regional Directors' Conference, Darwin, May, 1980.

References: References to journals and books should follow the criteria of the A.P.A., (see American Educational Research Journal, Vol.18, No.1, for a summary).

In the general text of the paper references should appear as Bernstein (1971) or Fisher and Fraser (1983), then these references should be placed in the reference list as,

BERNSTEIN, B. Class, codes and control. London, Routledge & Kegan Paul, 1971.

FISHER, D.L., & FRASER, B.J. A comparison of actual and preferred classroom environments as perceived by science teachers and students. Journal of Research in Science Teaching, 1983, 20, 55-61.

*Please note the order of dates, volume number, publisher, place of publication for books and journals, use of upper- and lower-case letters.